



DARK ENERGY
SURVEY

Y1P1 Calibrations Status (Single-Epoch)

DES-doc#7642

Douglas L. Tucker

Original: 17 Dec 2013 (@NCSA)

Update: 27 Dec 2013

Update: 15 Jan 2014 (DES@FNAL Science Mtg)

Update: 24 Jan 2014 (Global Calibrations Mtg.)

Update: 29 Jan 2014



Steps in the Global Photometric Calibration for Y1P1 (using GCM)

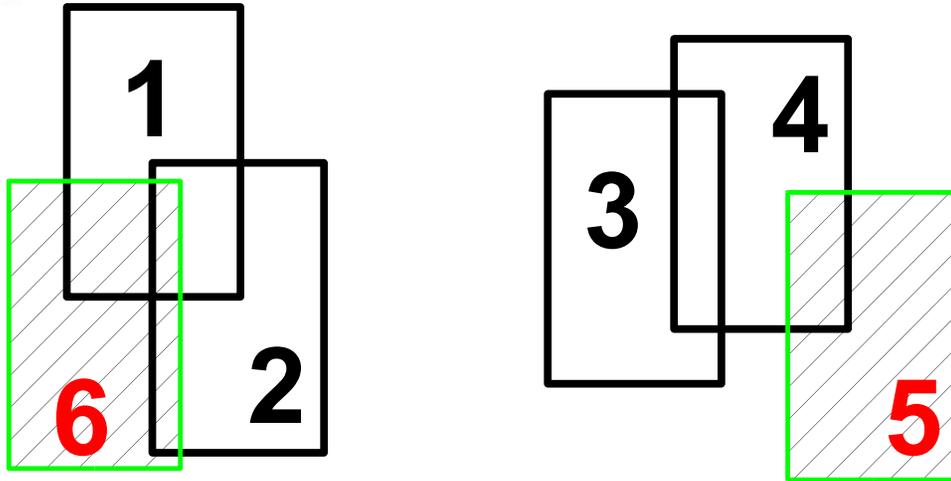
DARK ENERGY
SURVEY

1. **Pre-Calibrate:** create a set of local DES tertiary standards in each isolated Y1P1 area (Stripe 82 equatorial area, SPT area, SN areas) to tie the zeropoints to the DES AB system as well as to anchor the relative calibrations against gradients.
2. **StarMatch:** find all unique matches for star detections in the image-to-image overlaps and between star detections and the local tertiary standards.
3. **GCM-zeropoint:** solve for the photometric zeropoints for all the images observed in a given isolated Y1P1 area.
4. **NCSA Handoff:** hand off list of ccd image zeropoints to NCSA for uploading into database.



Global Calibration Module (GCM): Field-to-Field Zeropoints (I)

DARK ENERGY
SURVEY



A Generic Example:
Frames 5 & 6 are calibrated.
The others are uncalibrated.

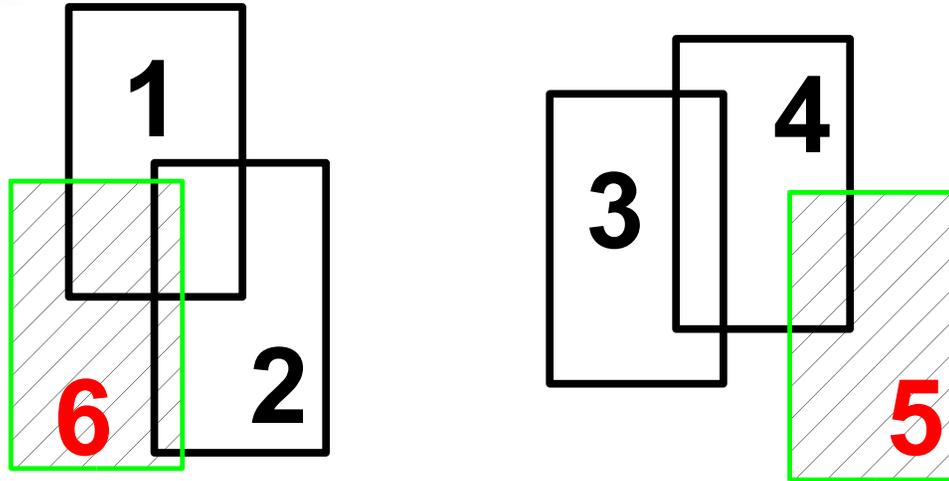
- Method used by Oxford-Dartmouth Thirty Degree Survey (MacDonald et al. 2004)
- Developed by Glazebrook et al. (1994) for an imaging K-band survey

- Consider n frames, of which $(1, \dots, m)$ are calibrated and $(m+1, \dots, n)$ are uncalibrated.
- Let $\Delta_{ij} = \langle \text{mag}_i - \text{mag}_j \rangle_{\text{pairs}}$ (note $\Delta_{ij} = -\Delta_{ji}$).
- Let ZP_i be the floating zero-point of frame i , but fixing $ZP_i = 0$ if $i > m$.
- Let $\theta_{ij} = 1$ if frames i and j overlap or if $i = j$; otherwise let $\theta_{ij} = 0$.
- Minimize $S = \sum \sum \theta_{ij} (\Delta_{ij} + ZP_i - ZP_j)^2$



Global Calibration Module (GCM): Field-to-Field Zeropoints (II)

DARK ENERGY
SURVEY



Example:

Frames **5** & **6** are calibrated.

The others are uncalibrated.

(From Glazebrook et al. 1994)

$$\begin{array}{|c|c|c|c|c|c|} \hline -2 & 1 & 0 & 0 & 0 & 1 \\ \hline 1 & -2 & 0 & 0 & 0 & 1 \\ \hline 0 & 0 & -1 & 1 & 0 & 0 \\ \hline 0 & 0 & 1 & -2 & 1 & 0 \\ \hline 0 & 0 & 0 & 0 & 1 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 1 \\ \hline \end{array} \times \begin{array}{|c|} \hline \text{ZP1} \\ \hline \text{ZP2} \\ \hline \text{ZP3} \\ \hline \text{ZP4} \\ \hline \text{ZP5} \\ \hline \text{ZP6} \\ \hline \end{array} = \begin{array}{|c|} \hline \Delta_{12} + \Delta_{16} \\ \hline \Delta_{21} + \Delta_{26} \\ \hline \Delta_{34} \\ \hline \Delta_{43} + \Delta_{45} \\ \hline 0 \\ \hline 0 \\ \hline \end{array}$$



DARK ENERGY
SURVEY

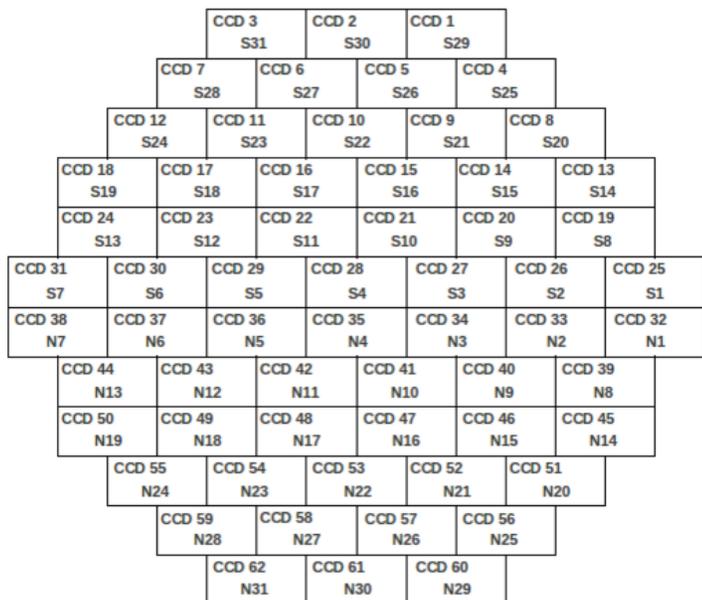
GCM for DES

Options:

1. Calibrate CCD image
by CCD image

2. Calibrate exposure by
exposure

- assumes CCD-to-CCD
relative ZPs are essentially
constant, e.g., during
photometric, non-dome-
occluded conditions





GCM for DES

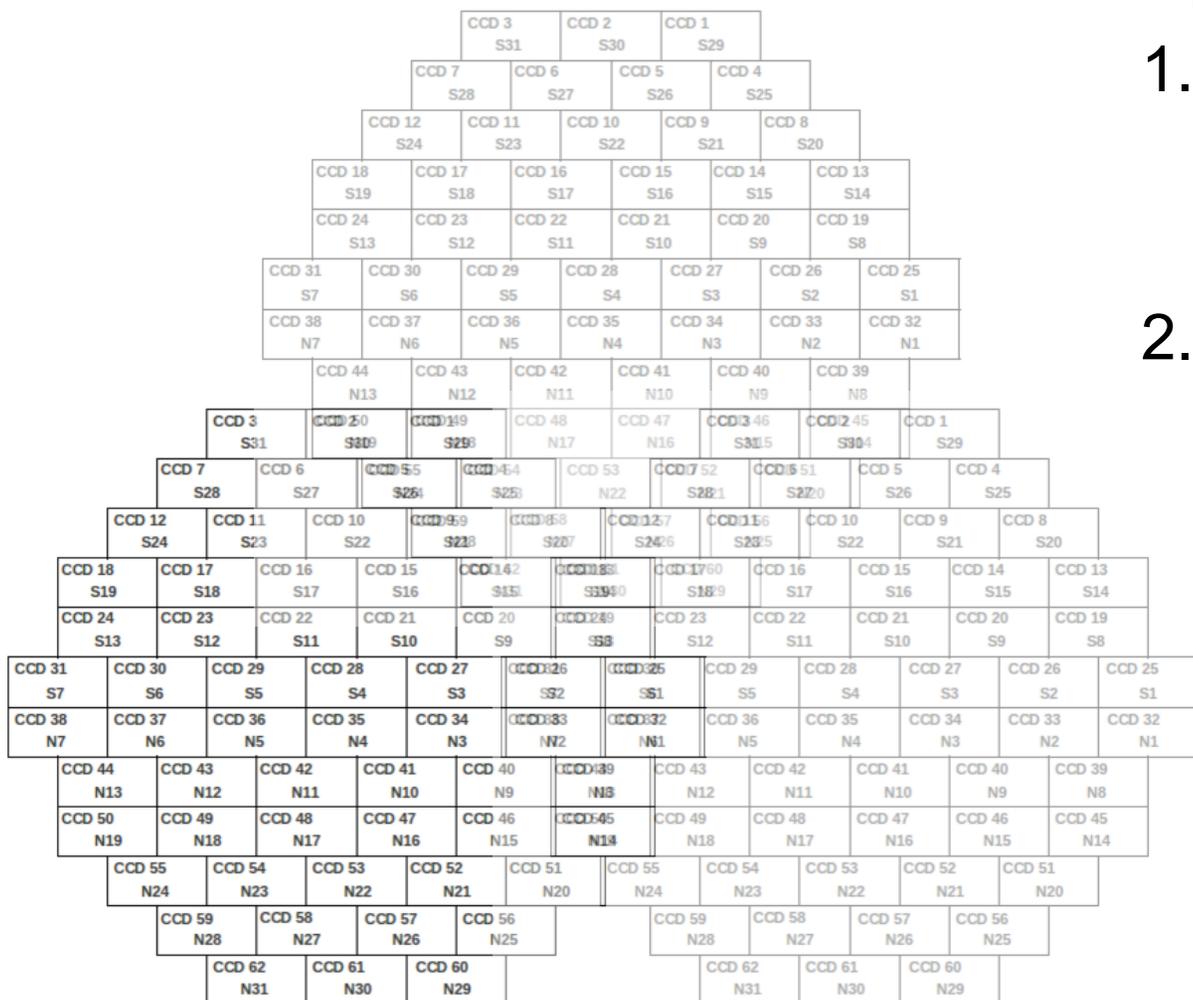
DARK ENERGY
SURVEY

Options:

1. Calibrate CCD image by CCD image

2. Calibrate exposure by exposure

- assumes CCD-to-CCD relative ZPs are essentially constant, e.g., during photometric, non-dome-occluded conditions

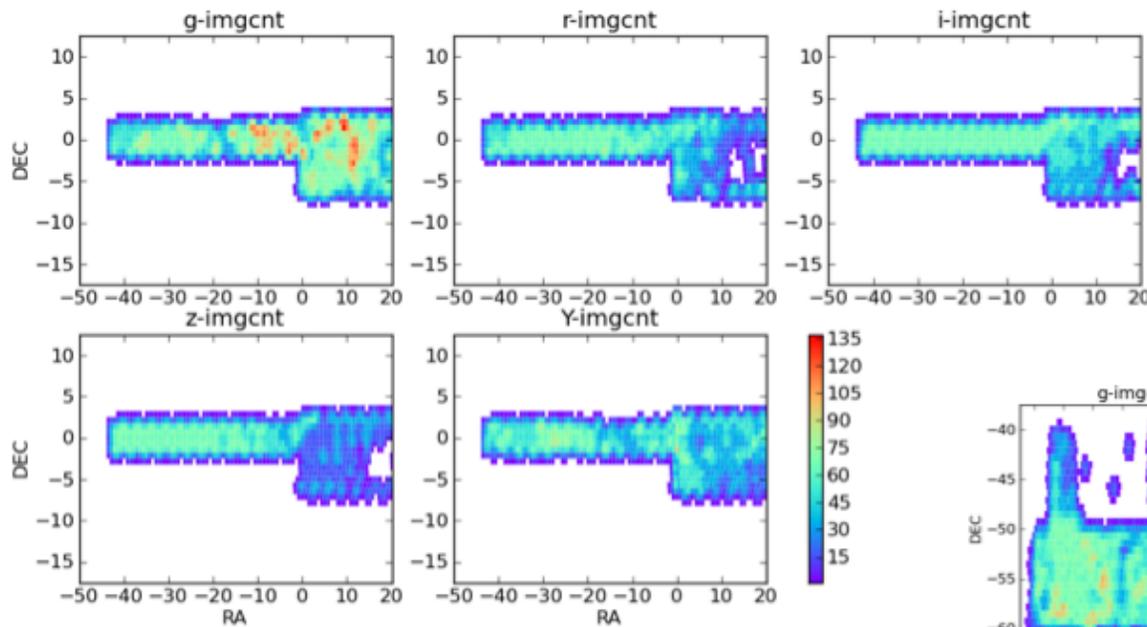




The Y1P1 Region

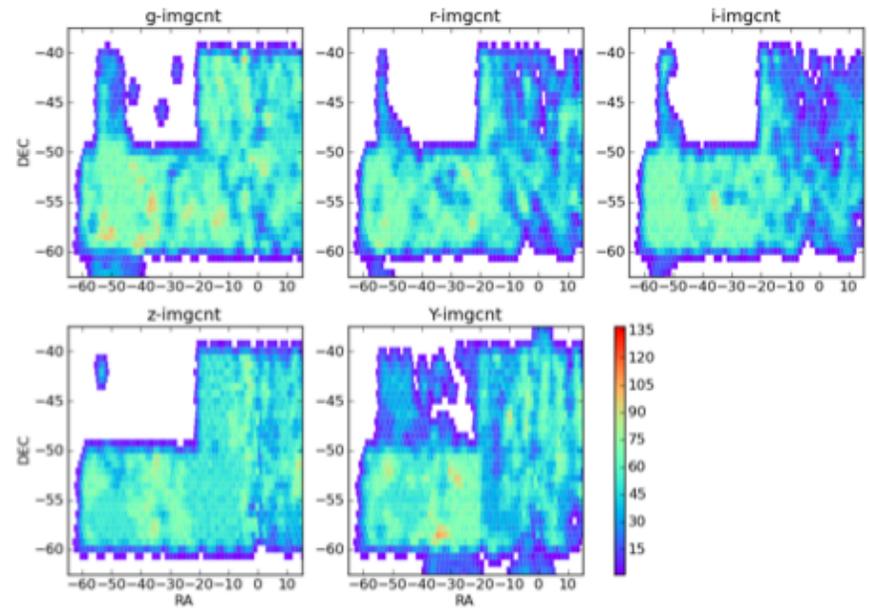
(credit: R. Gruendl)

DARK ENERGY
SURVEY



Stripe 82

SPT (western end)





DARK ENERGY
SURVEY

Stripe 82 Equatorial Area

- Lots of overlap with SDSS DR10.
- → “Punt” and just use SDSS DR10 (transformed into the DES AB mag system) as local tertiary standards.
- Perform a single-pass GCM solution, solving for photometric zeropoints on a CCD image by CCD image basis.



Y1P1 Equatorial Area Query

DARK ENERGY
SURVEY

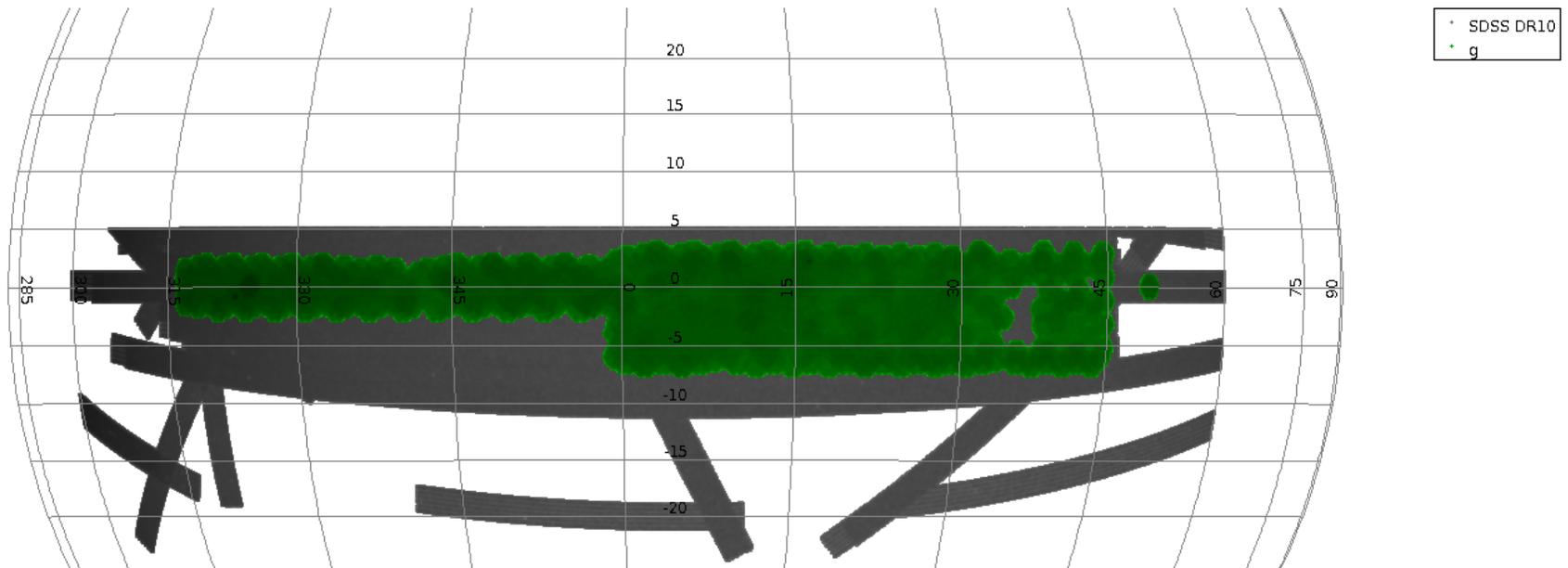
```
SELECT e.id as exposureid, o.imageid, o.object_id, o.x_image,  
       o.y_image, o.ra, o.dec, o.mag_psf, o.magerr_psf, o.zeropoint, o.zeropointid,  
       3600.*o.fwhm_world as fwhm_arcsec, o.spread_model, o.flags,  
       e.nite, i.run, e.propid, e.object, e.band, i.ccd, e.airmass,  
       e.mjd_obs, e.exptime, e.photflag, i.skybrite, i.skysigma,  
       i.elliptic as image_ellipt, 0.27*i.fwhm as image_fwhm_arcsec,  
       i.saturate as image_sat_level, i.imagetype, ev.*, rasicam.*  
FROM exposure e  
JOIN image i ON i.exposureid=e.id  
JOIN objects_current o ON o.imageid=i.id  
JOIN runtag r ON r.run=i.run  
JOIN gruendl.firstcut_eval_v3 ev ON ev.exposureid=e.id  
JOIN gruendl.rasicam_decam rasicam ON rasicam.exposureid=e.id  
WHERE (r.tag='Y1N_FIRSTCUT') AND  
       (e.mjd_obs BETWEEN 56533.0 AND 56631.9) AND i.imagetype='red' AND  
       (UPPER(ev.accepted)='TRUE') AND (UPPER(rasicam.source)='HEADER') AND  
       (e.object NOT LIKE '%SN%' AND e.object NOT LIKE '%S%half-CCD offset%') AND  
       (e.telra BETWEEN 300.0 AND 360.0) AND (e.teldec BETWEEN -10.0 AND 10.0) AND (o.flags=0) AND  
       ((o.spread_model + 3*o.spreaderr_model) BETWEEN -0.003 AND 0.003 ) AND (o.mag_psf > 0.01) AND  
       ((o.mag_psf - (o.zeropoint-25.0) + 2.5*log(10,e.exptime)) BETWEEN 15.0 AND 21.0 )
```

(Also includes equatorial
nightly standard star fields)



Y1P1 Equatorial Area vs. SDSS DR10: g-band

DARK ENERGY
SURVEY



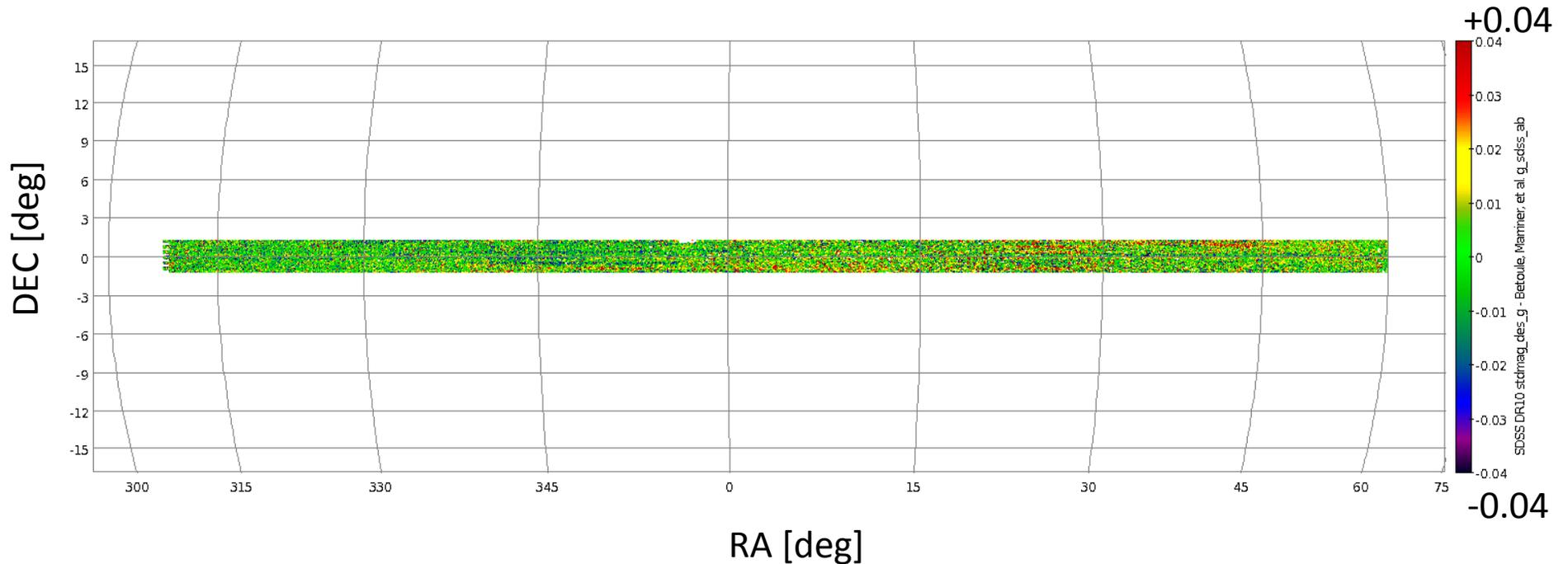
- Tie directly to DES-transformed SDSS DR10
- Calibrate CCD image by CCD image



Cross-Check on Std Star Catalog: SDSS DR10 vs. Betoule et al. (2013)

DARK ENERGY
SURVEY

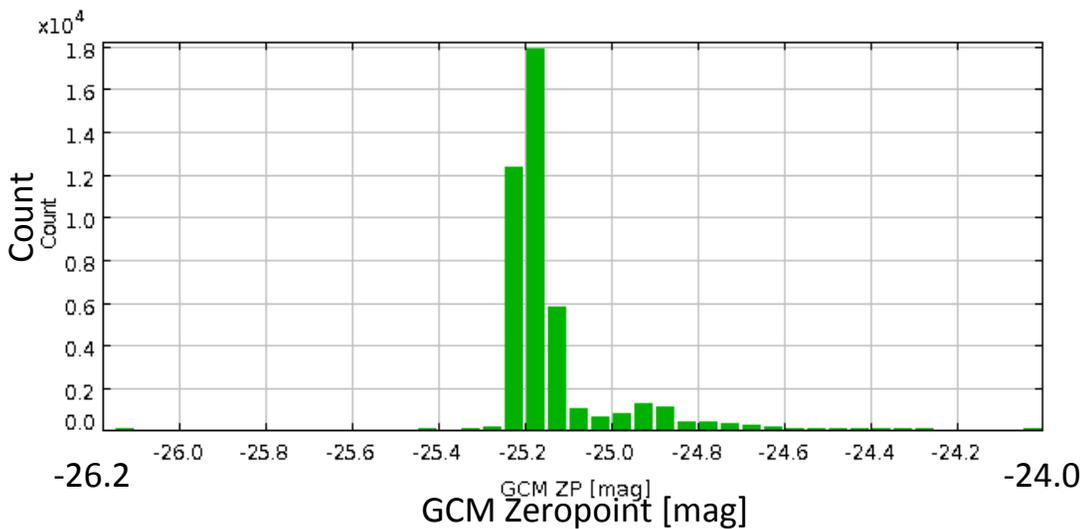
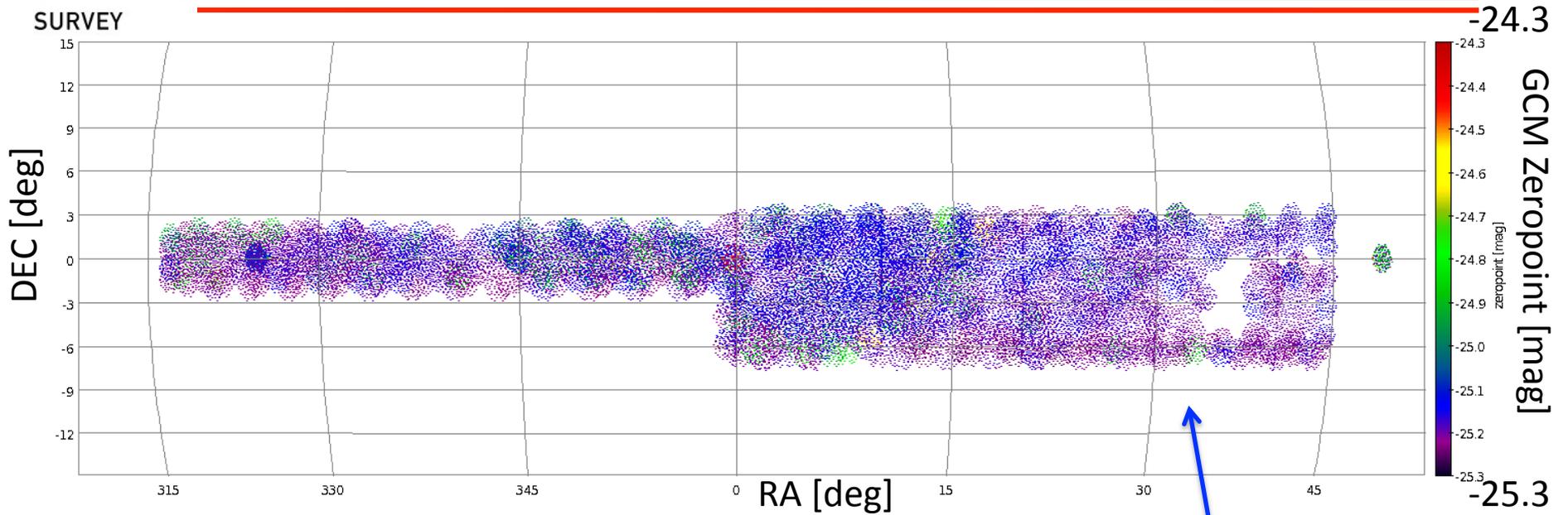
SDSS Stripe 82 g-band transformed to DES ABmag
SDSS DR10 minus Betoule, Marriner, Regnault, et al. (2013)





GCM Zeropoints: g-band

DARK ENERGY
SURVEY

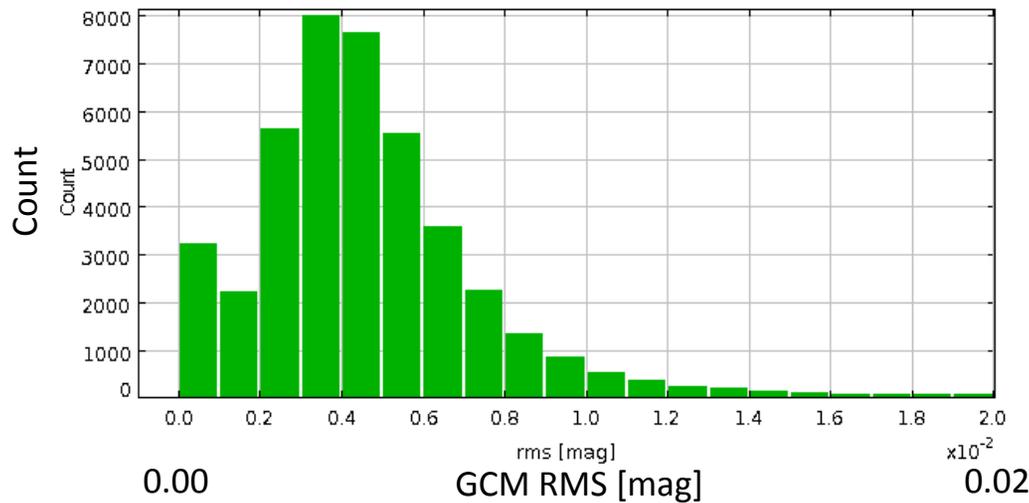
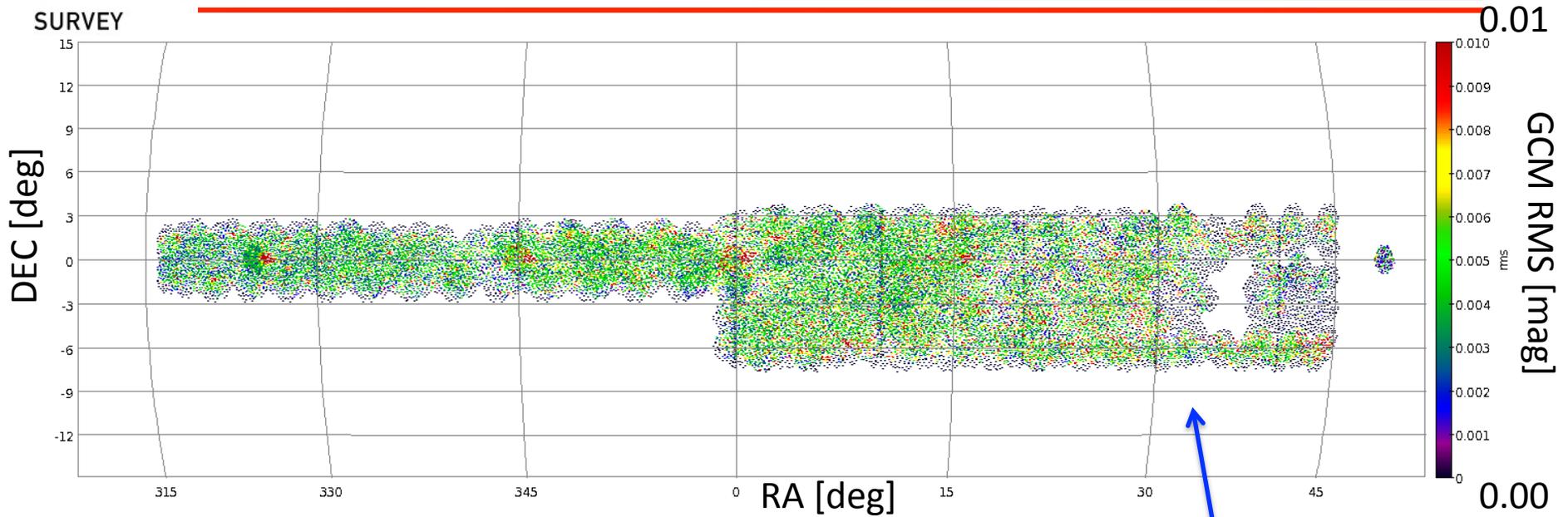


Each "point" is an
Individual CCD image



GCM RMS's (internal errors): g-band

DARK ENERGY
SURVEY



Each "point" is an
Individual CCD image

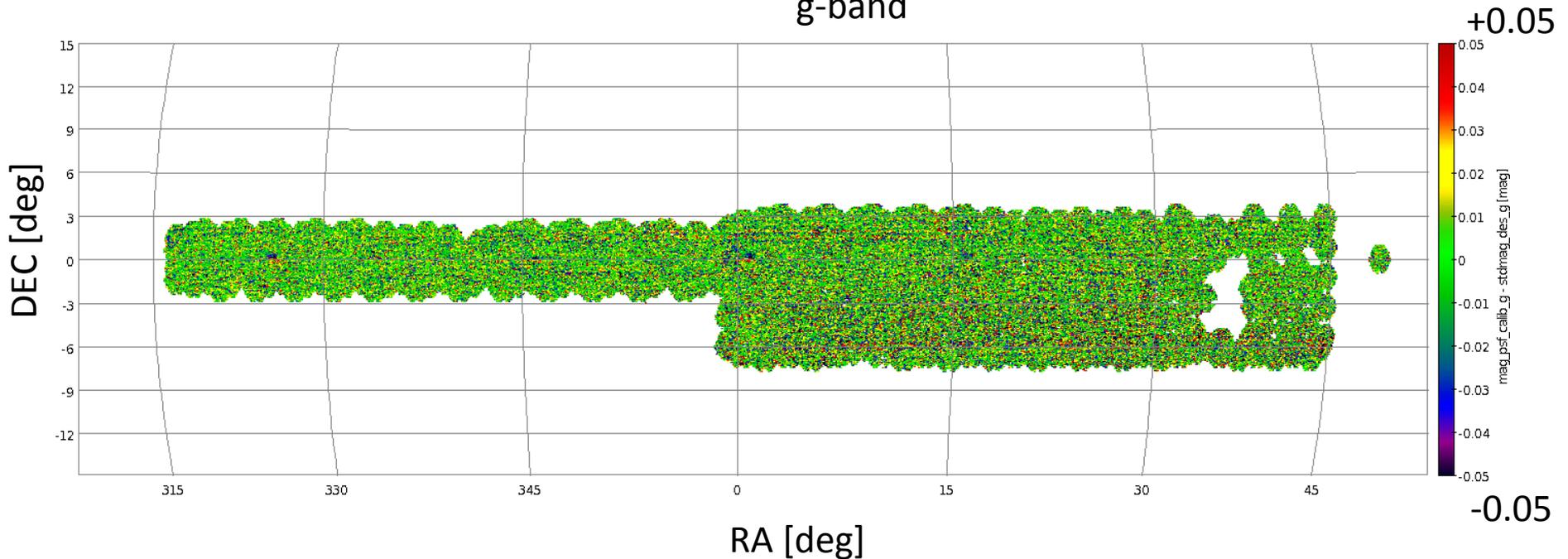
← (Note that the x-axis is in units of 0.01 mag)



DARK ENERGY
SURVEY

Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag*

GCM-calibrated mag_psf minus stdmag* vs. (RA,DEC):
g-band

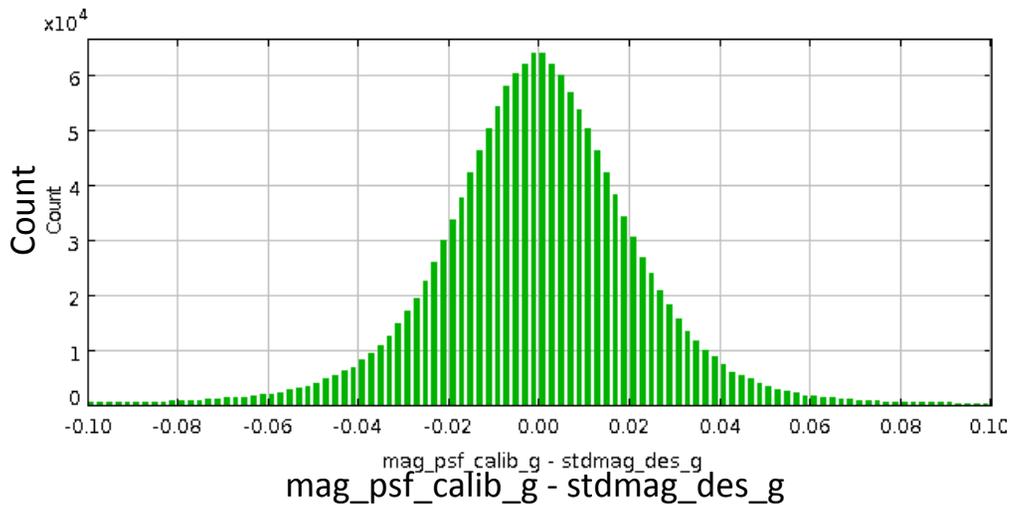
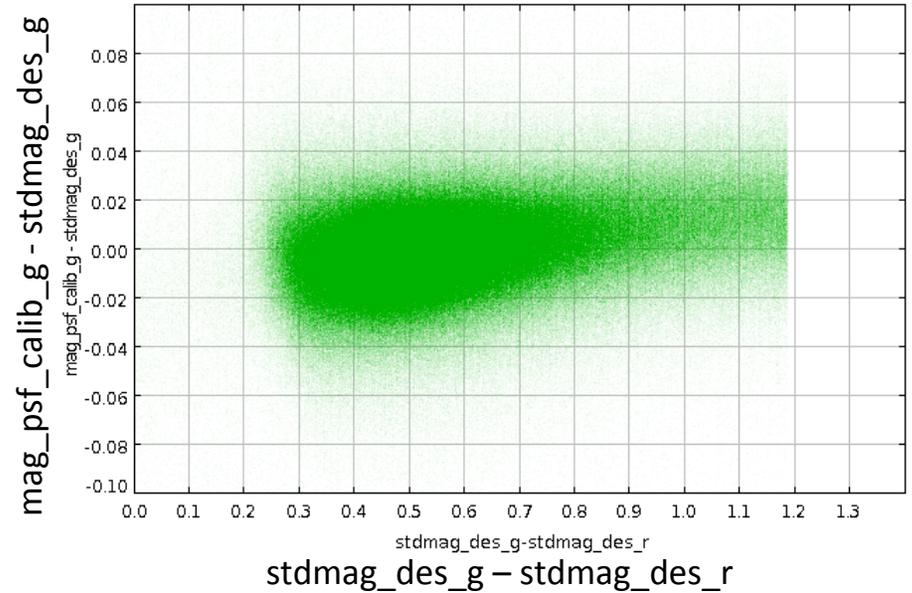
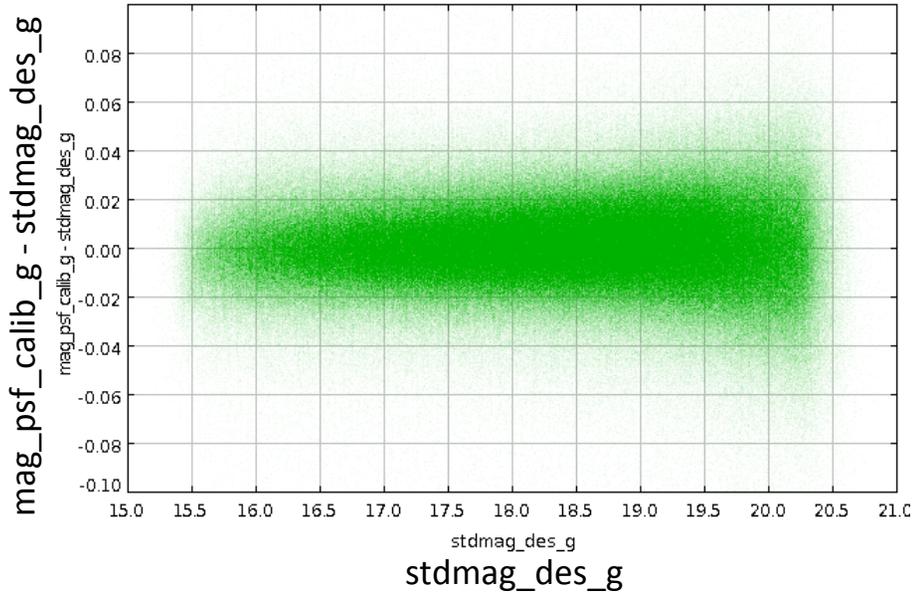


*stdmag = SDSS DR10 mag transformed to DES AB mag



Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag^*

DARK ENERGY
SURVEY



↑
Note residual color term

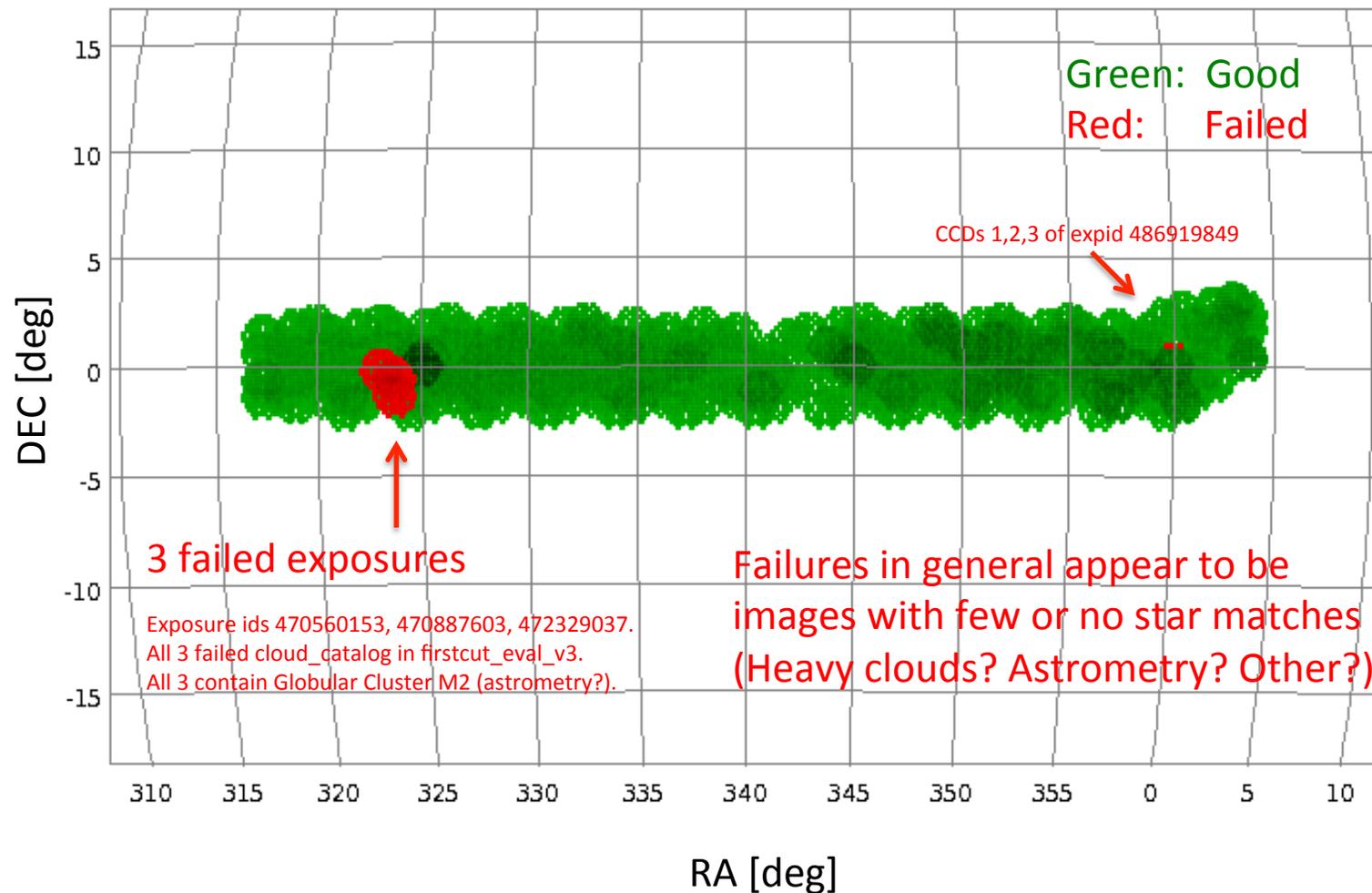
* stdmag = SDSS DR10 mag
transformed to DES AB mag



DARK ENERGY
SURVEY

GCM Failed CCD Images in Strict Y1P1 Equatorial Area

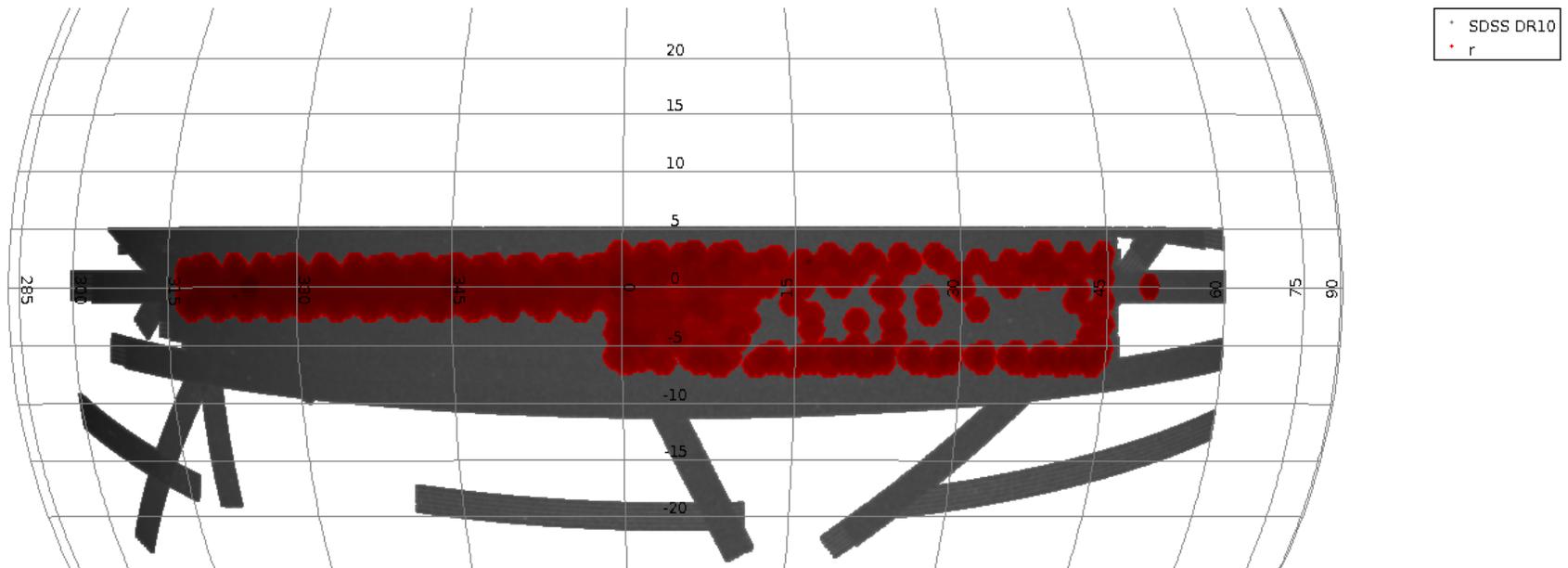
g-band: 184 failed out of total of 15,921 CCD images (1.15%)





Y1P1 Equatorial Area vs. SDSS DR10: r-band

DARK ENERGY
SURVEY

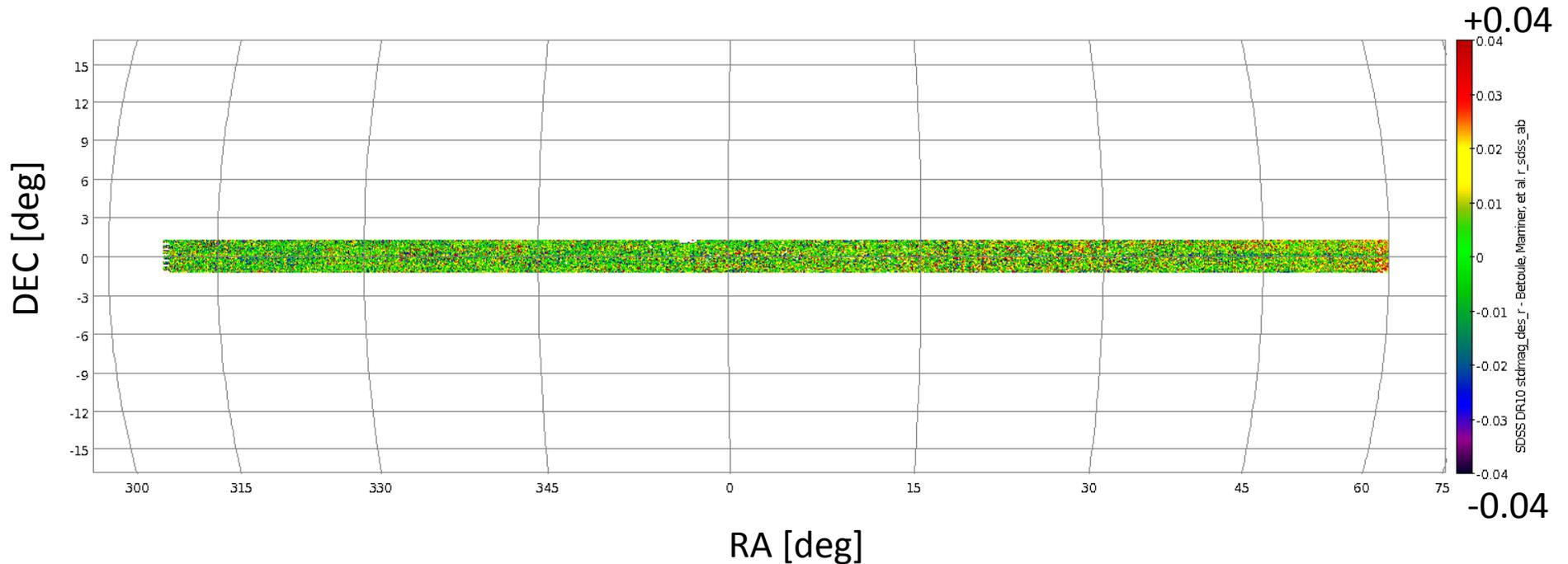




Cross-Check on Std Star Catalog: SDSS DR10 vs. Betoule et al. (2013)

DARK ENERGY
SURVEY

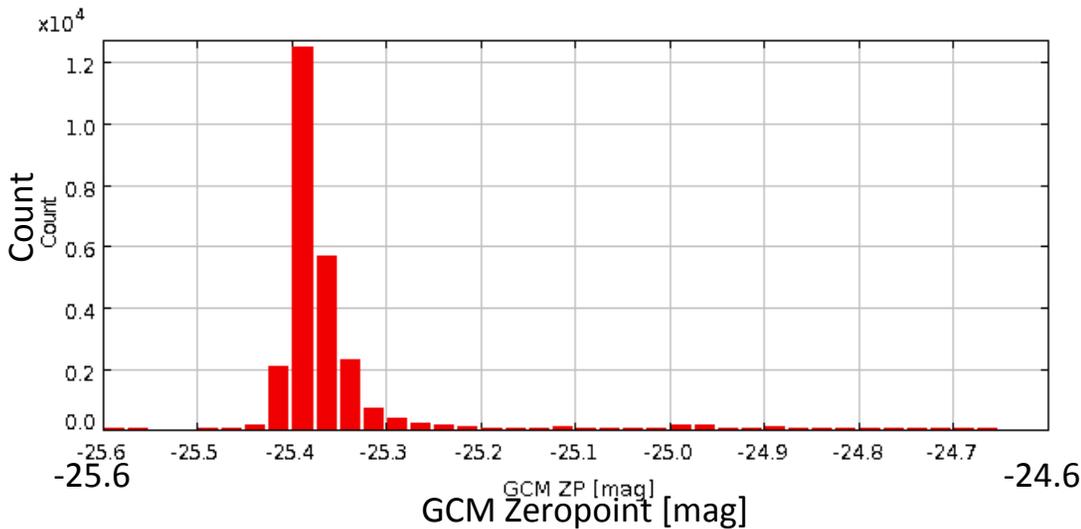
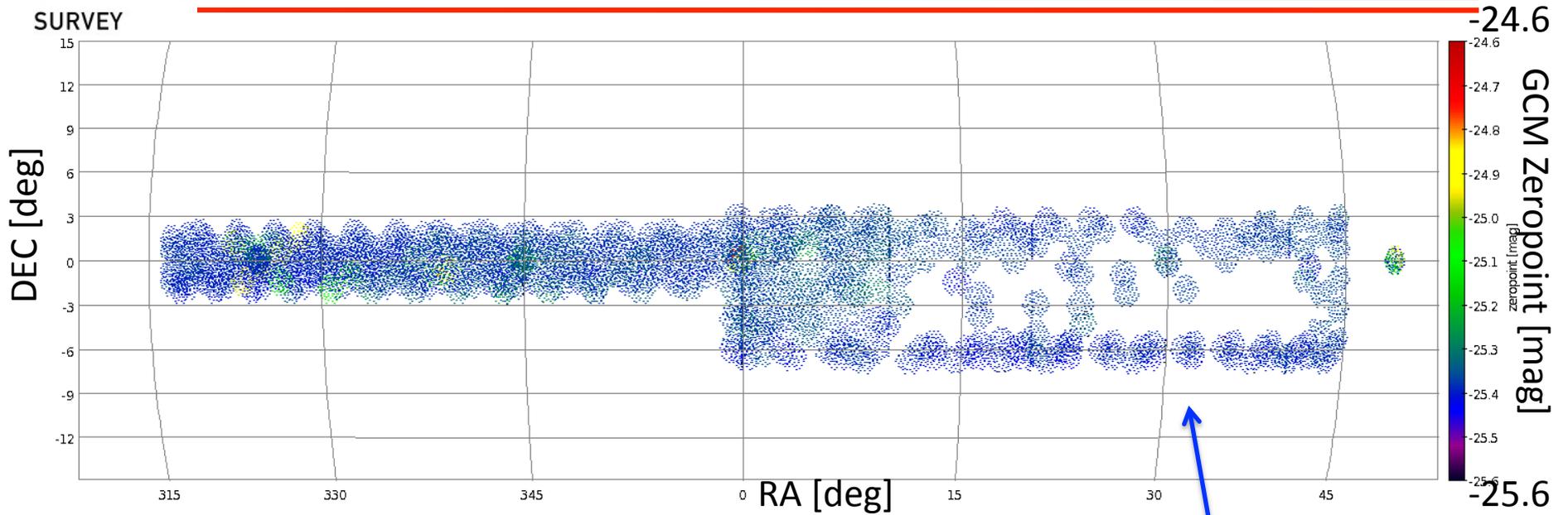
SDSS Stripe 82 r-band transformed to DES ABmag
SDSS DR10 minus Betoule, Marriner, Regnault, et al. (2013)





GCM Zeropoints: r-band

DARK ENERGY
SURVEY

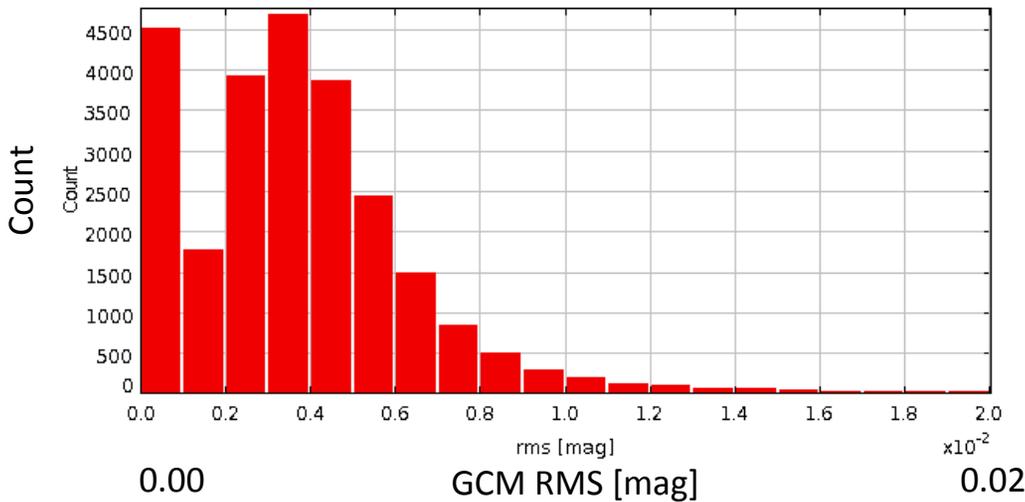
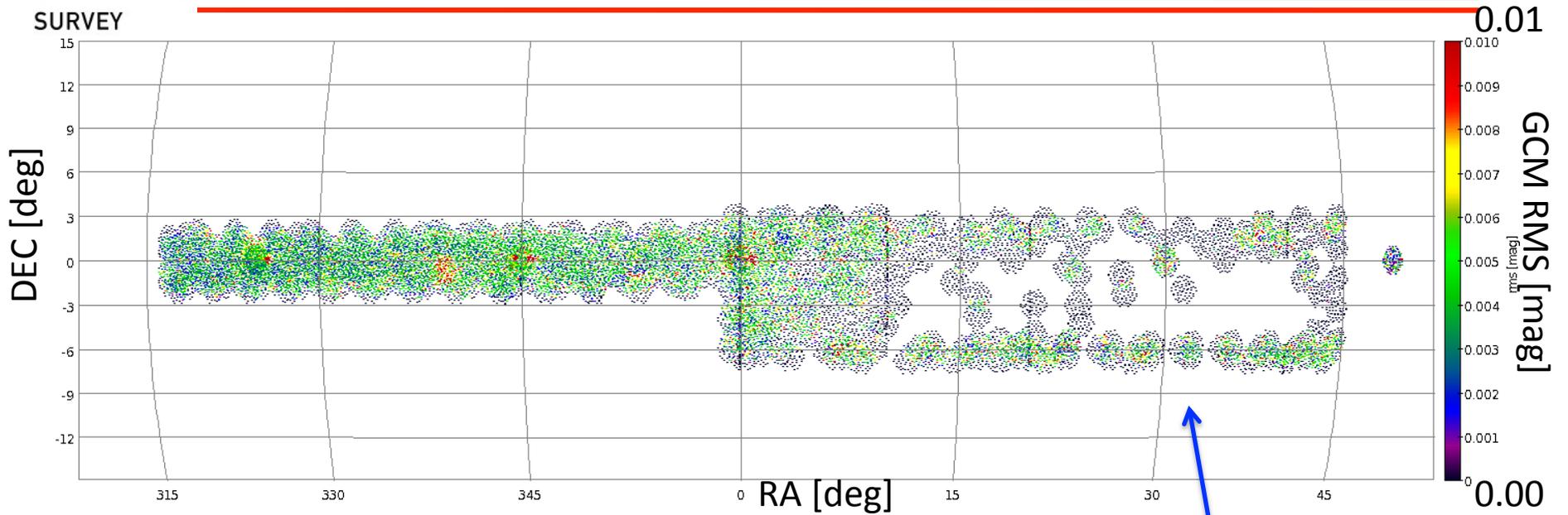


Each "point" is an
Individual CCD image



GCM RMS's (internal errors): r-band

DARK ENERGY
SURVEY



Each "point" is an
Individual CCD image

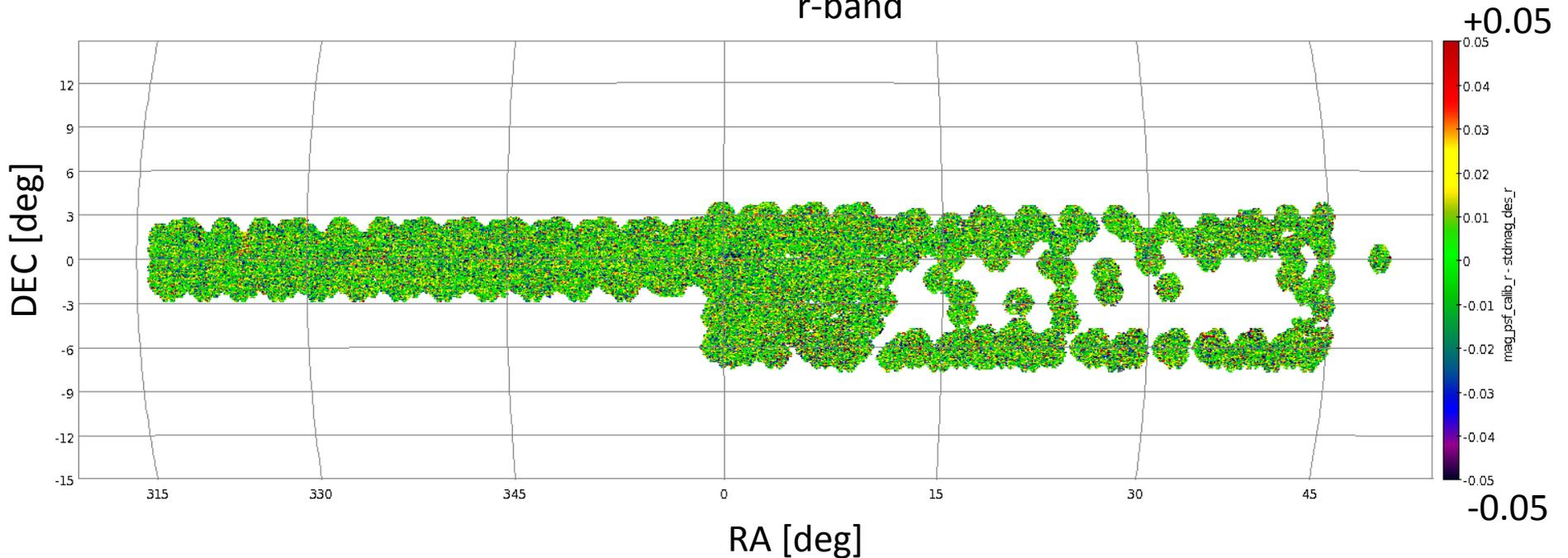
← (Note that the x-axis is in units of 0.01 mag)



DARK ENERGY
SURVEY

Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag*

GCM-calibrated mag_psf minus stdmag* vs. (RA,DEC):
r-band

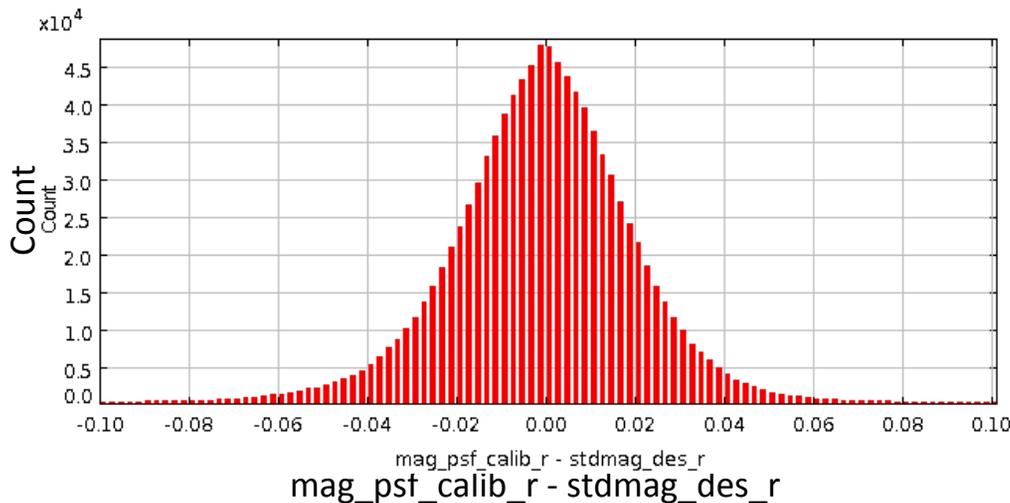
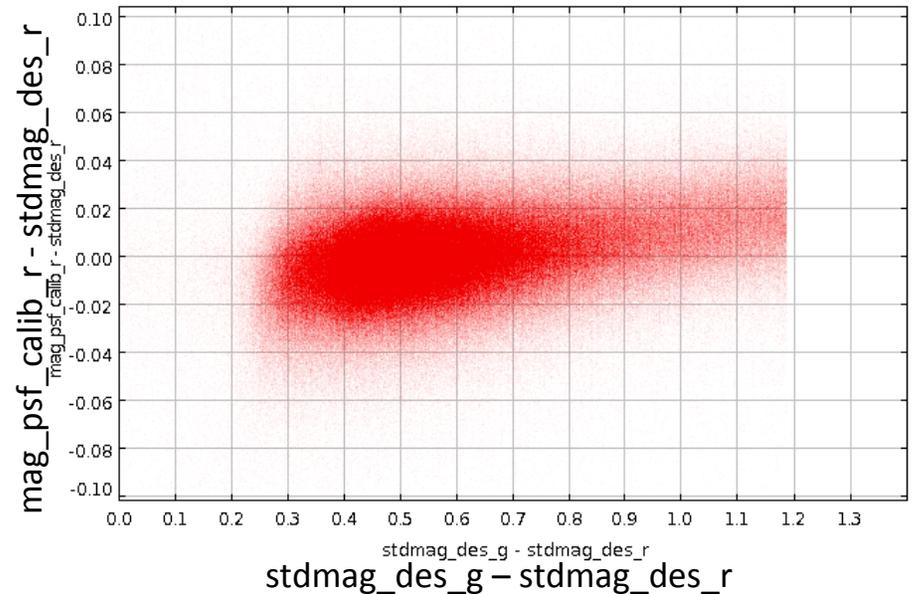
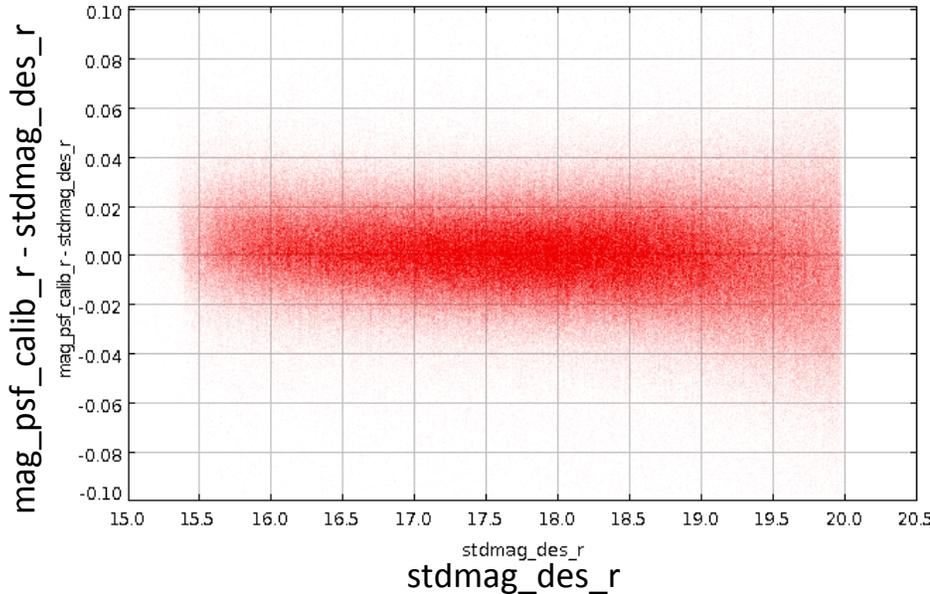


*stdmag = SDSS DR10 mag transformed to DES AB mag



Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag*

DARK ENERGY
SURVEY



Note residual color term

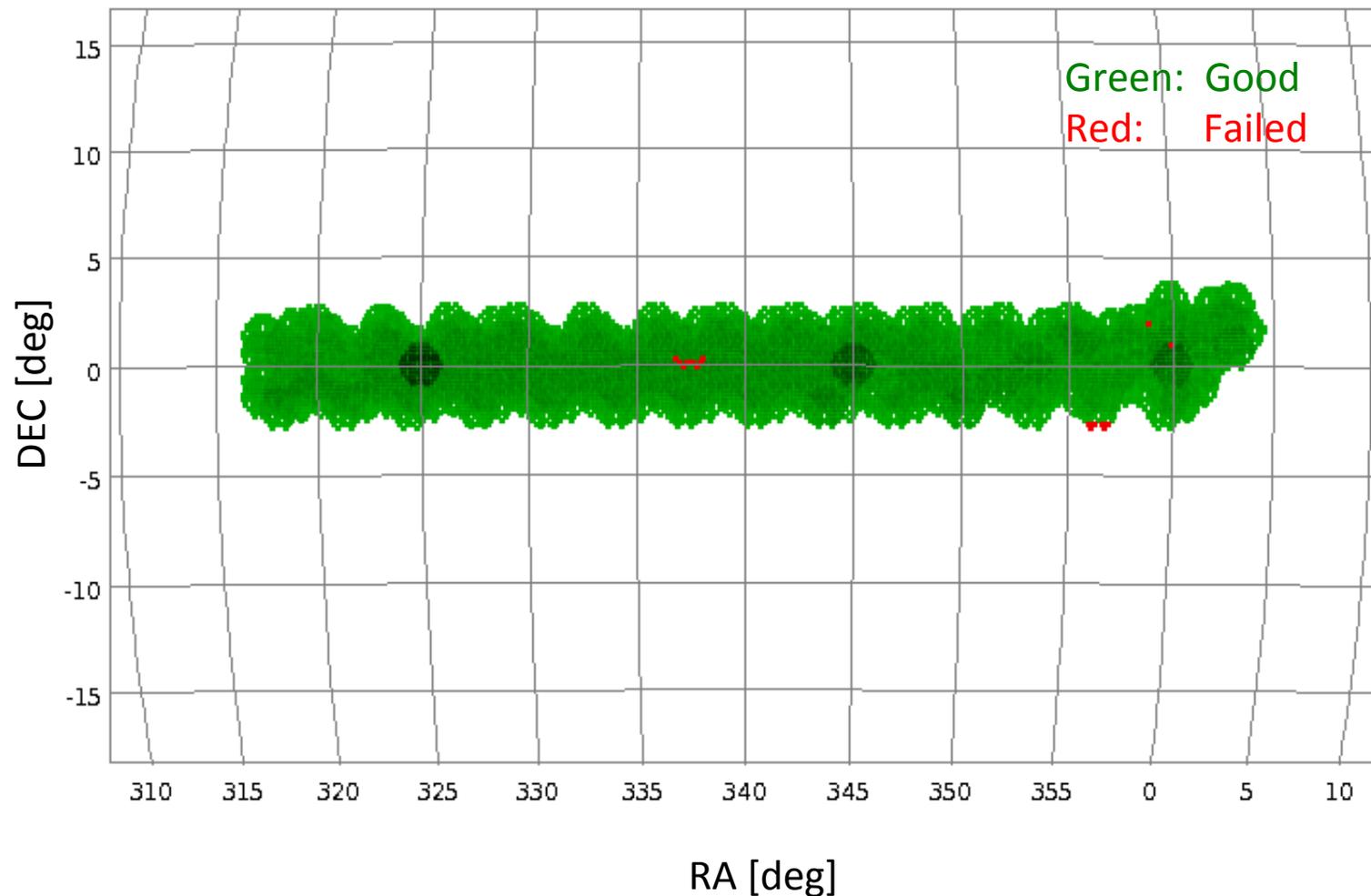
*stdmag = SDSS DR10 mag transformed to DES AB mag



GCM Failed CCD Images in Strict Y1P1 Equatorial Area

DARK ENERGY
SURVEY

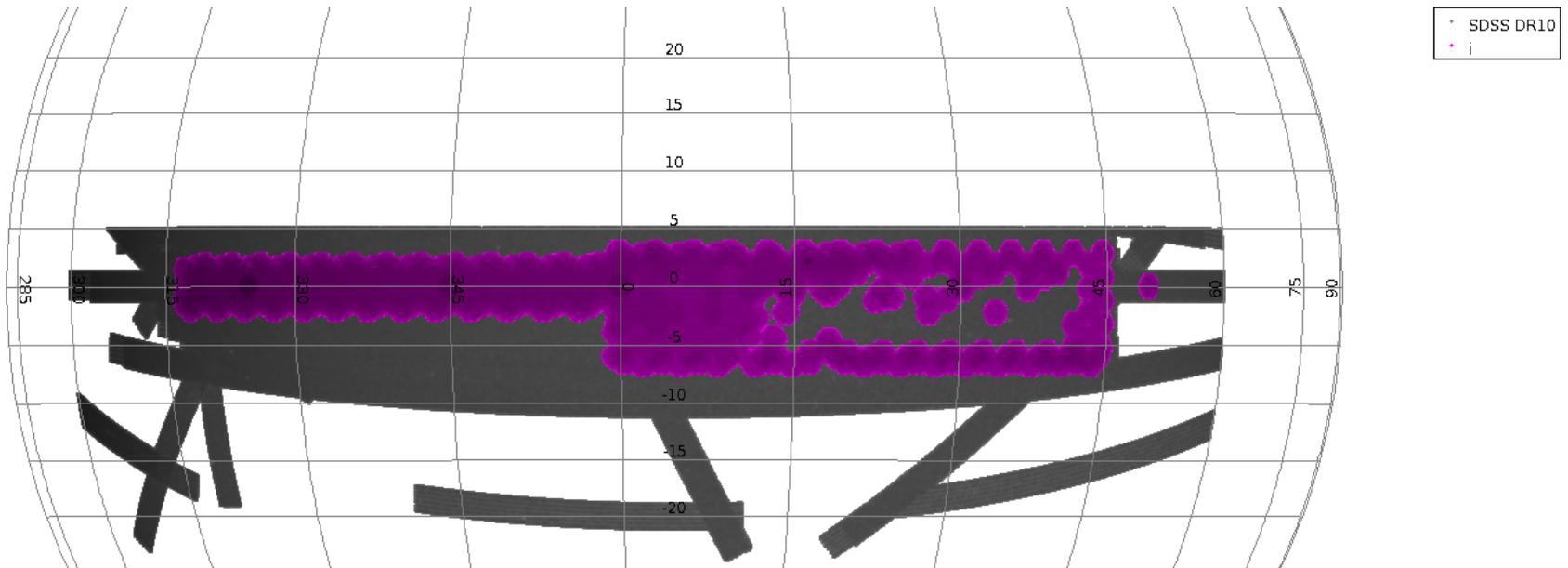
r-band: 16 failed out of total of 13,908 CCD images (0.12%)





Y1P1 Equatorial Area vs. SDSS DR10: i-band

DARK ENERGY
SURVEY

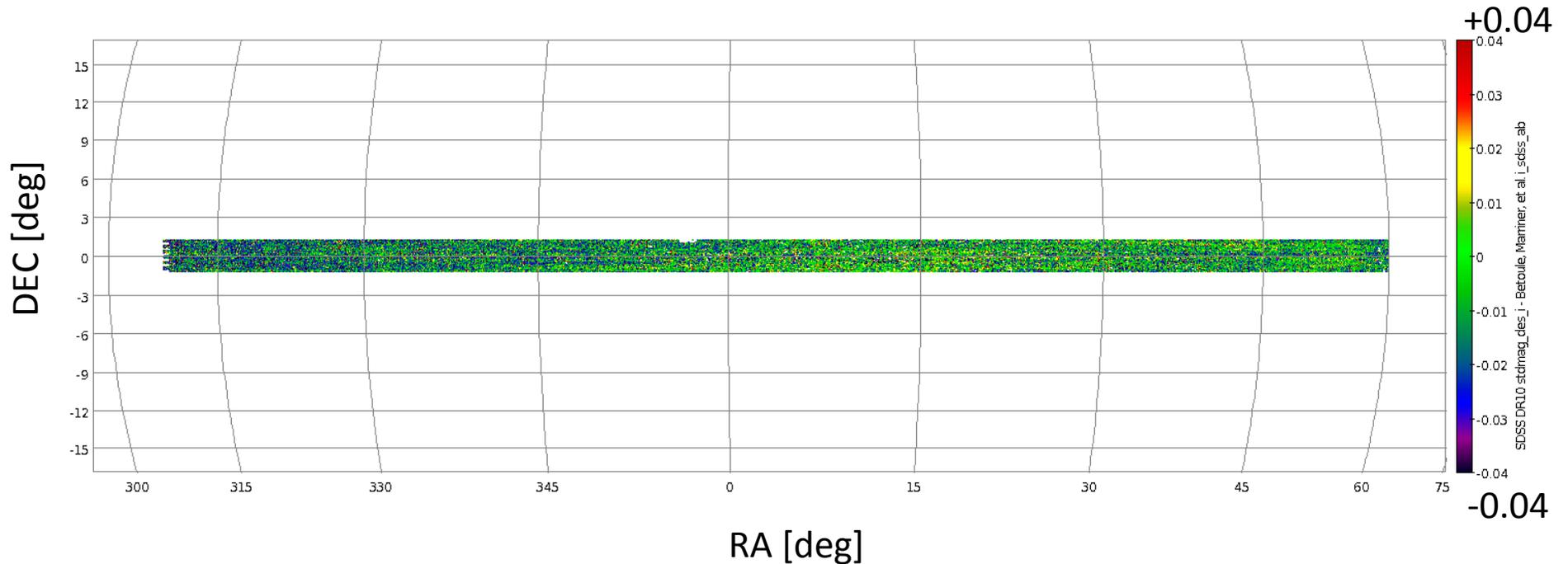




Cross-Check on Std Star Catalog: SDSS DR10 vs. Betoule et al. (2013)

DARK ENERGY
SURVEY

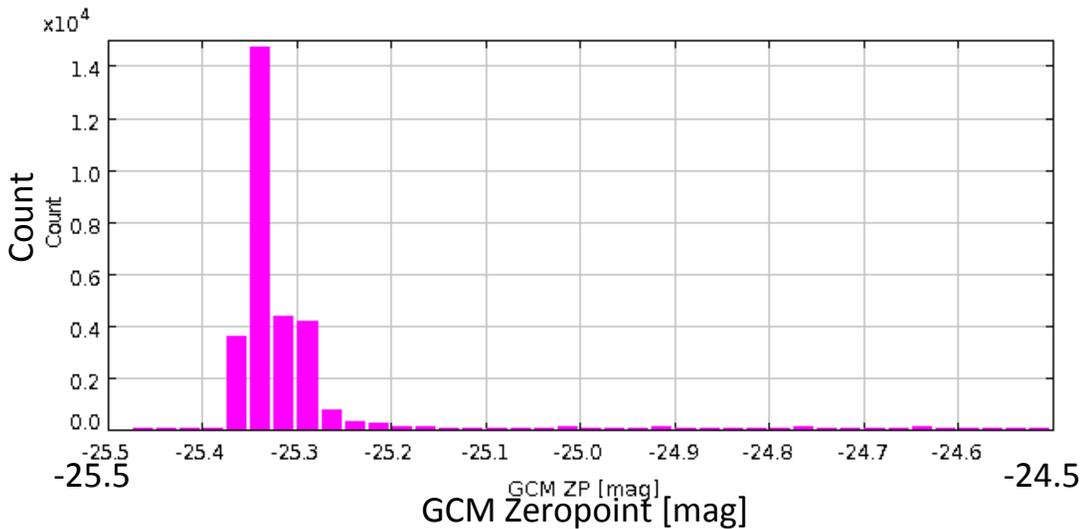
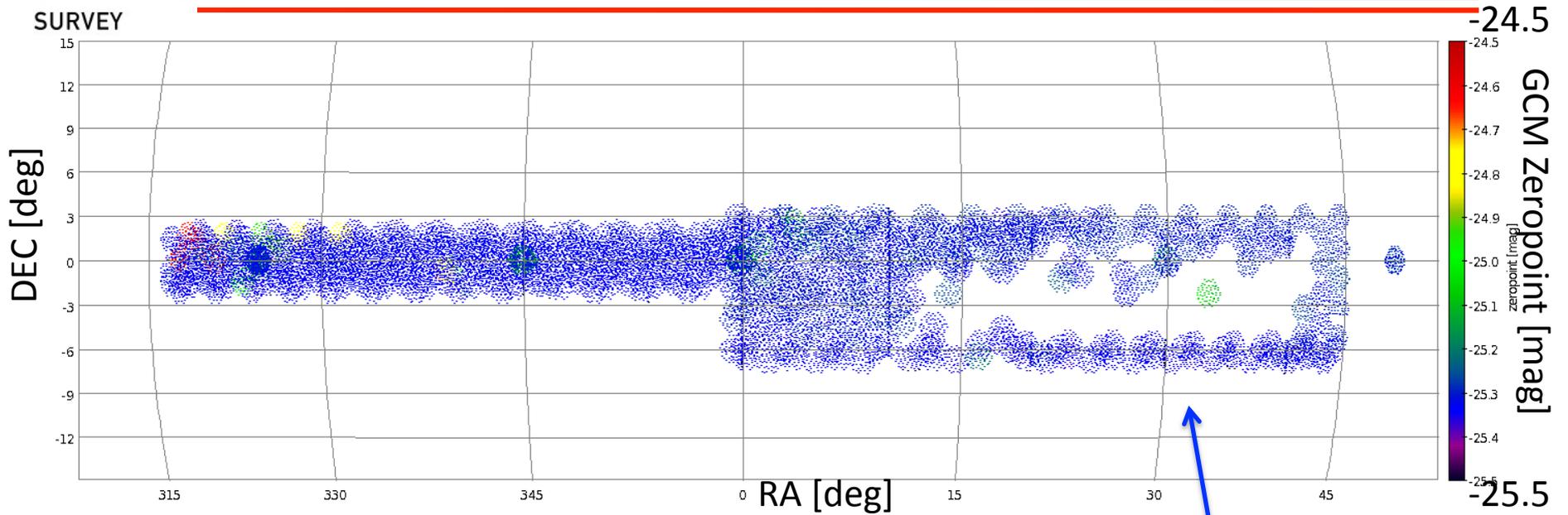
SDSS Stripe 82 i-band transformed to DES ABmag
SDSS DR10 minus Betoule, Manner, Regnault, et al. (2013)





GCM Zeropoints: i-band

DARK ENERGY
SURVEY

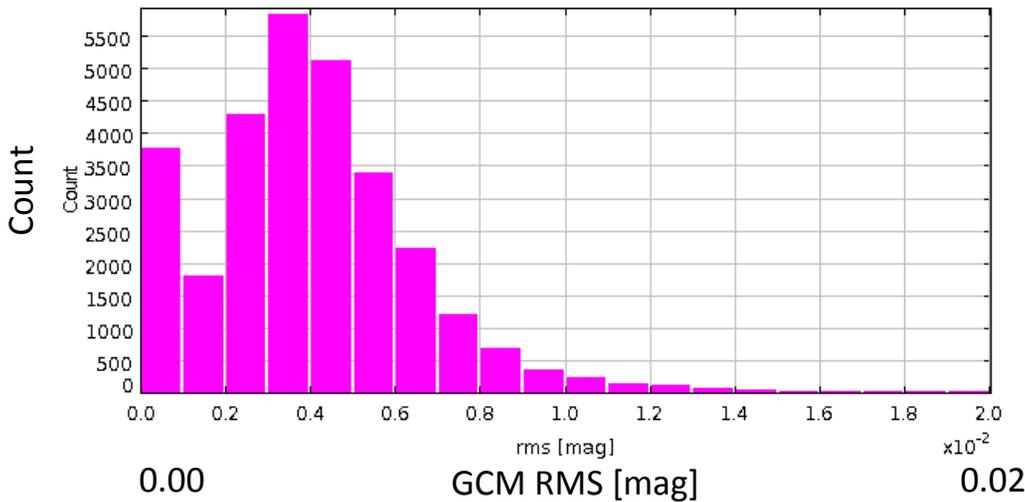
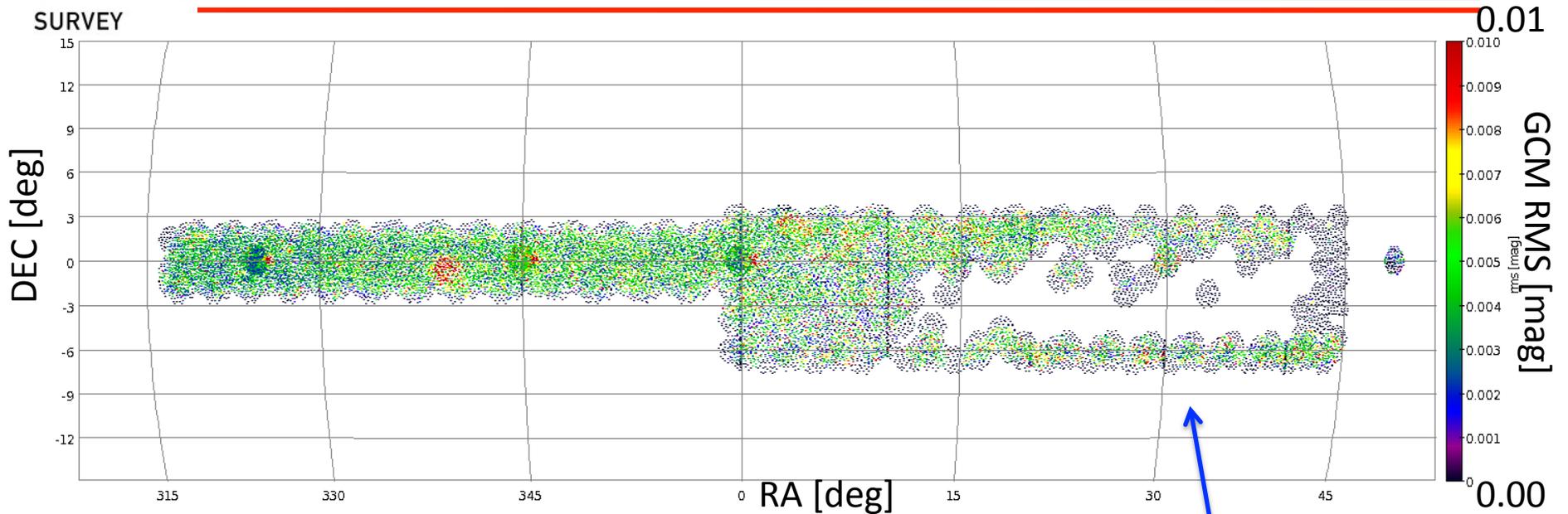


Each "point" is an
Individual CCD image



GCM RMS's (internal errors): i-band

DARK ENERGY
SURVEY



Each "point" is an
Individual CCD image

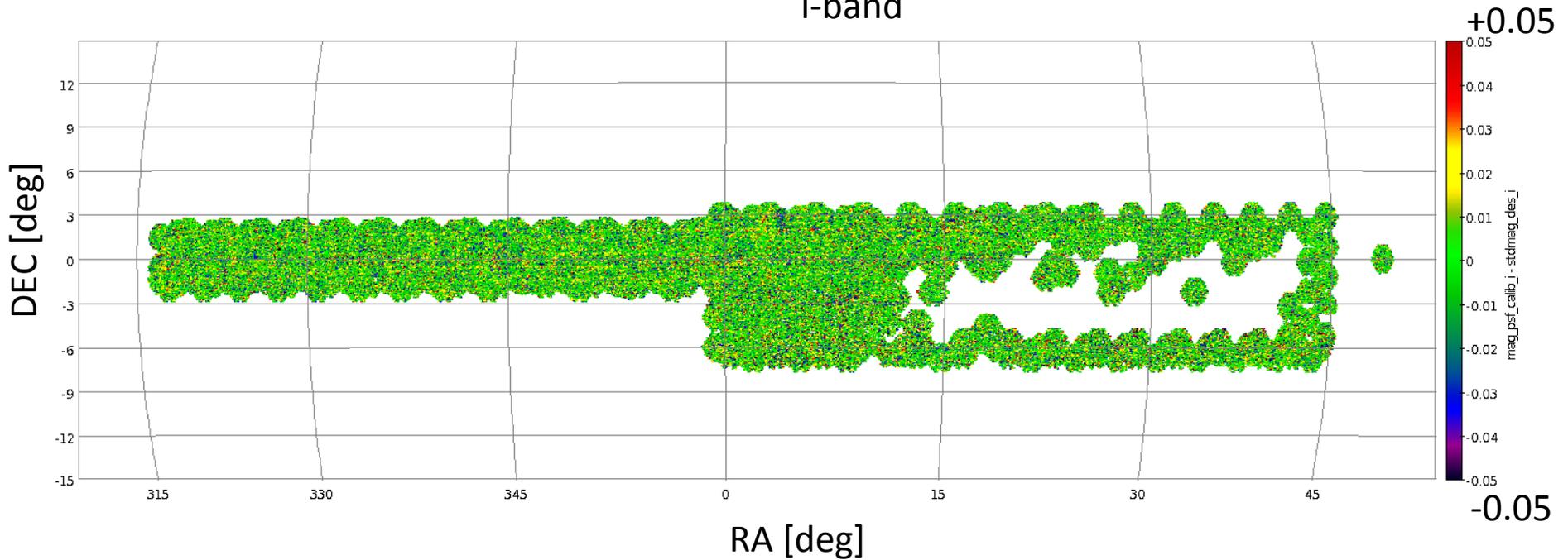
← (Note that the x-axis is in units of 0.01 mag)



DARK ENERGY
SURVEY

Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag*

GCM-calibrated mag_psf minus stdmag* vs. (RA,DEC):
i-band

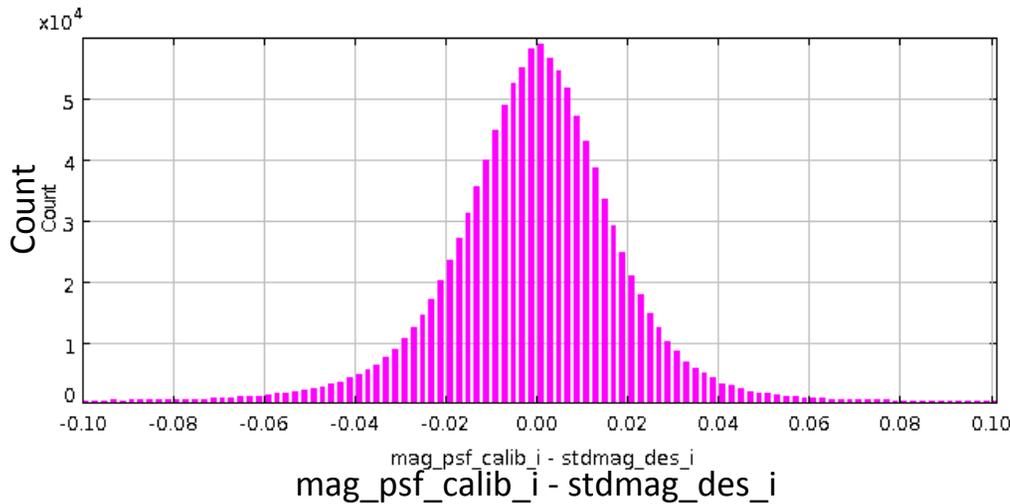
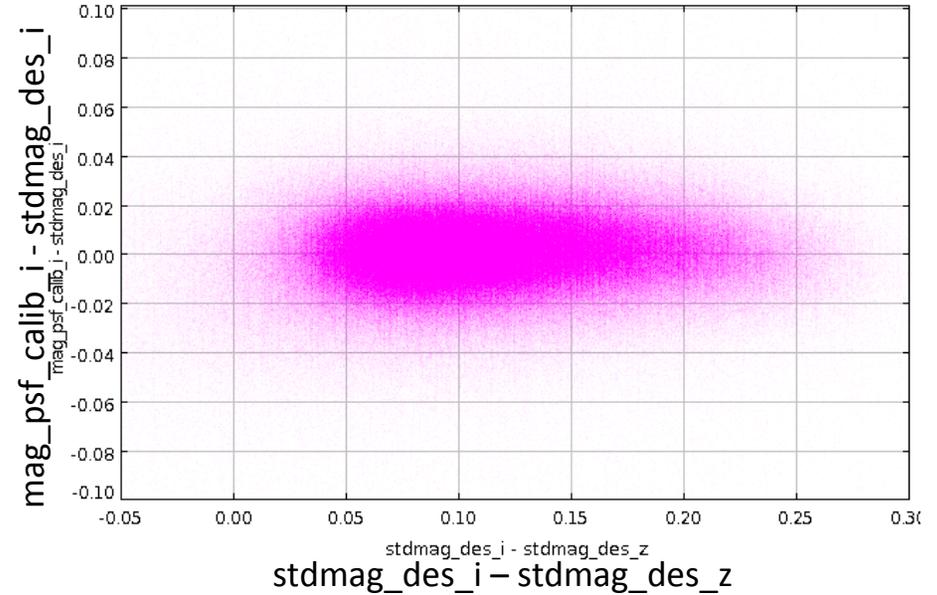
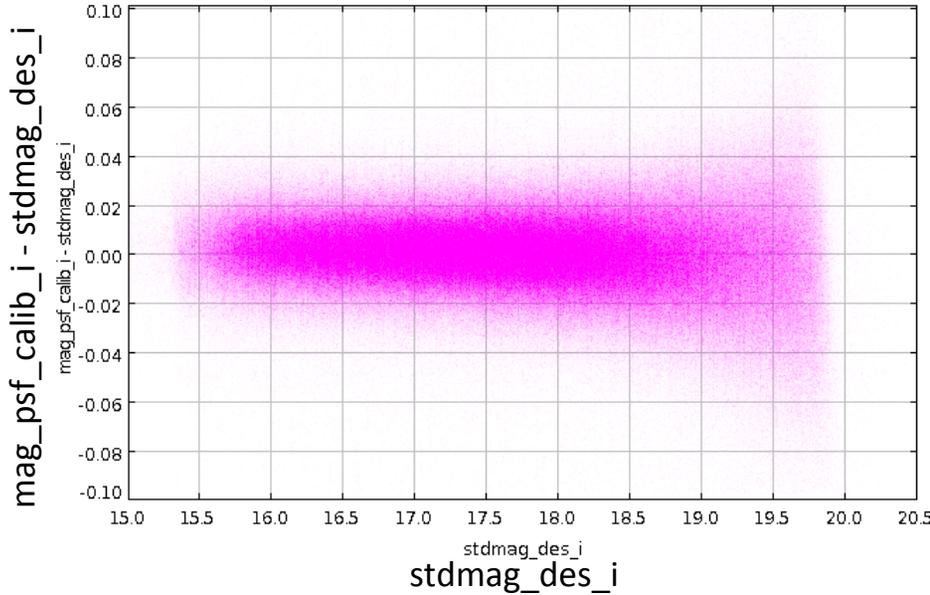


*stdmag = SDSS DR10 mag transformed to DES AB mag



Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag^*

DARK ENERGY
SURVEY



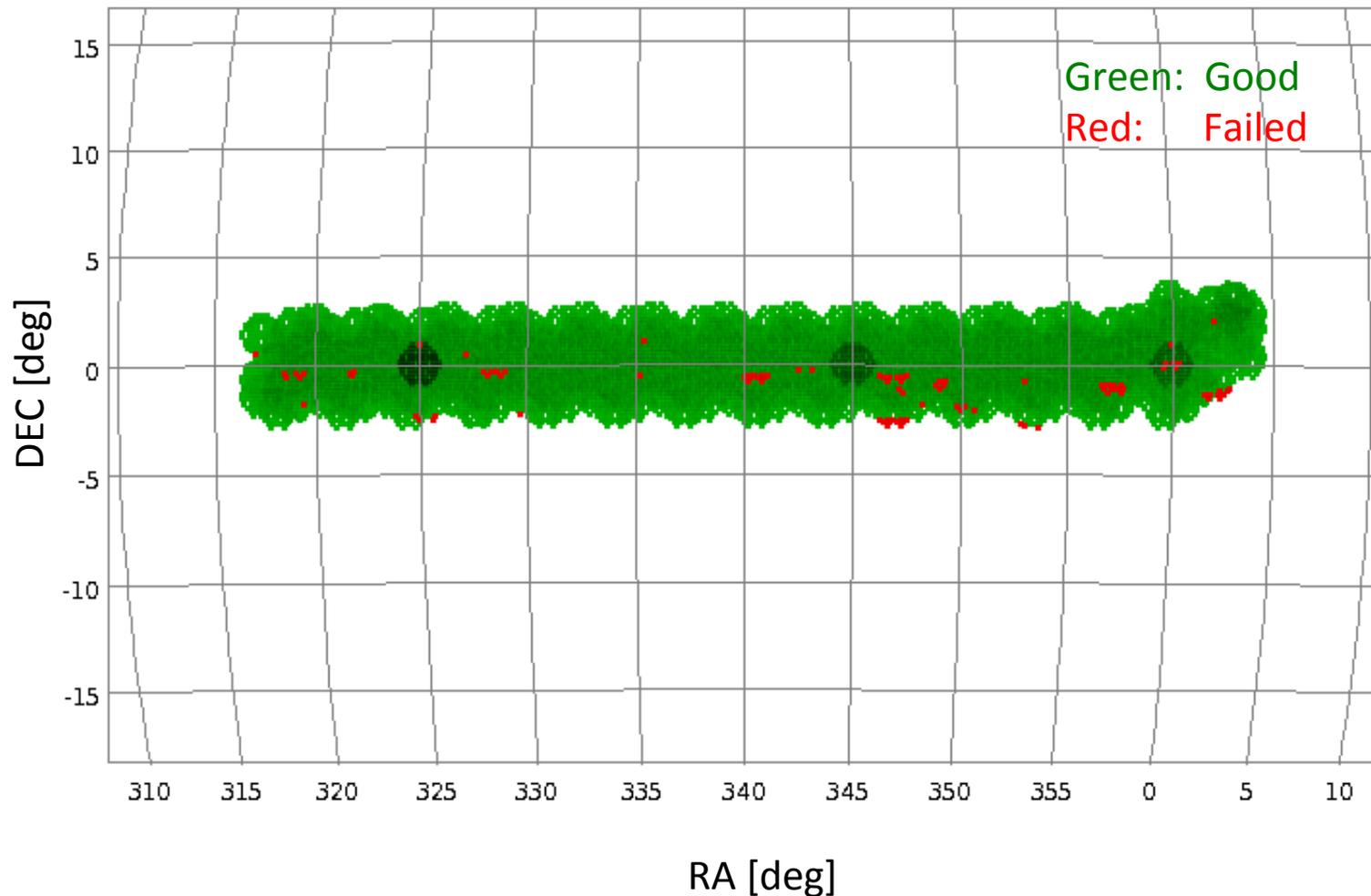
* stdmag = SDSS DR10 mag
transformed to DES AB mag



DARK ENERGY
SURVEY

GCM Failed CCD Images in Strict Y1P1 Equatorial Area

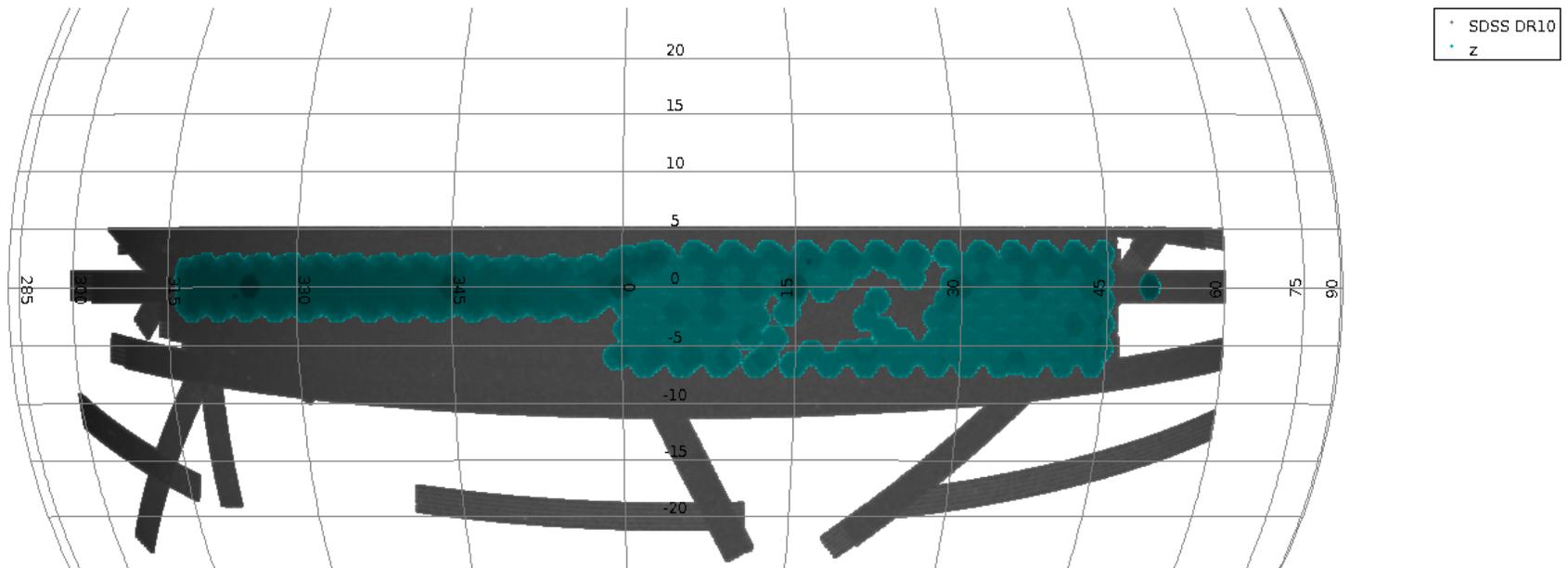
i-band: 98 failed out of total of 15,616 CCD images (0.63%)





Y1P1 Equatorial Area vs. SDSS DR10: z-band

DARK ENERGY
SURVEY

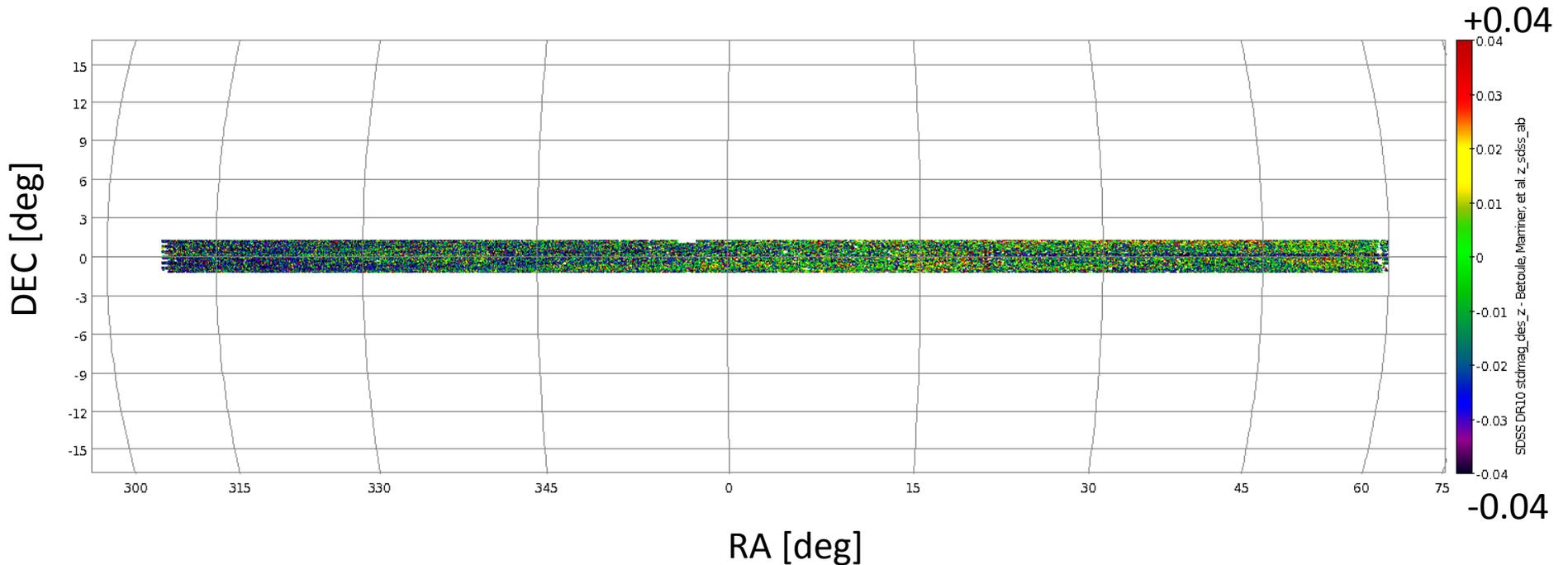




Cross-Check on Std Star Catalog: SDSS DR10 vs. Betoule et al. (2013)

DARK ENERGY
SURVEY

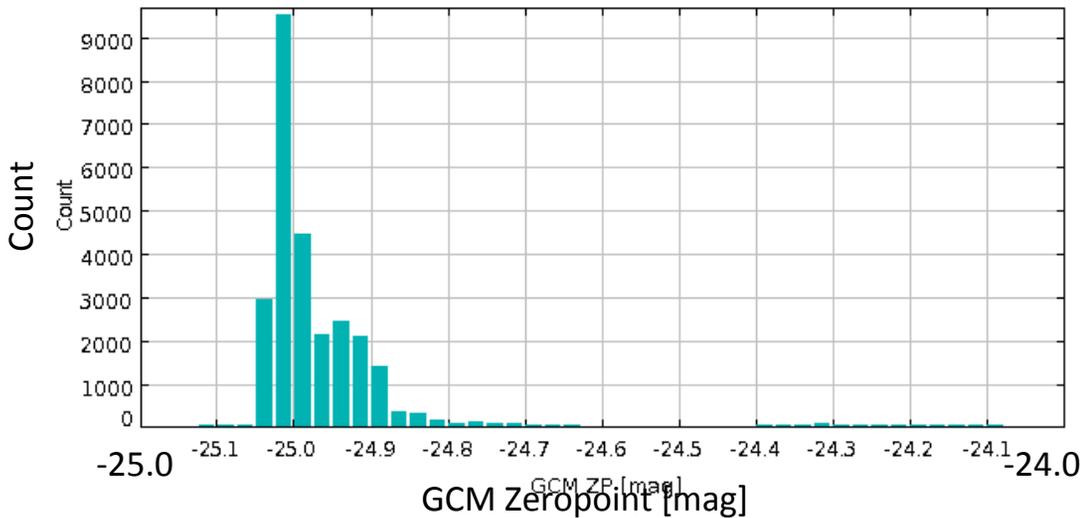
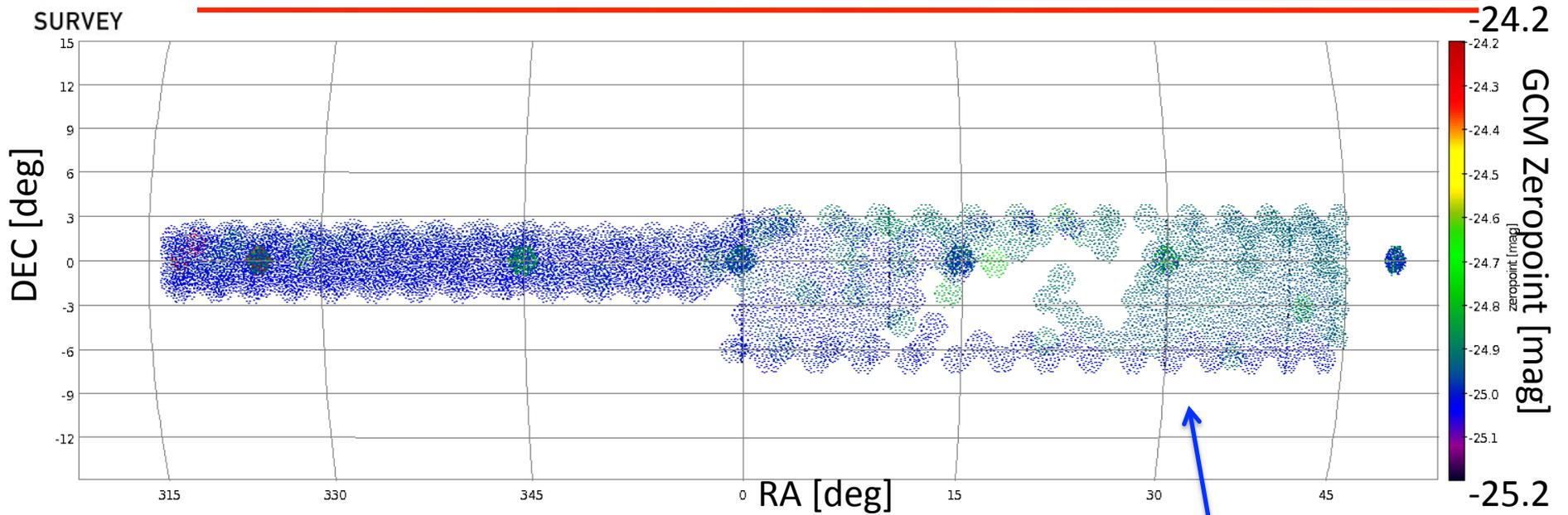
SDSS Stripe 82 z-band transformed to DES ABmag
SDSS DR10 minus Betoule, Marnier, Regnault, et al. (2013)





GCM Zeropoints: z-band

DARK ENERGY
SURVEY

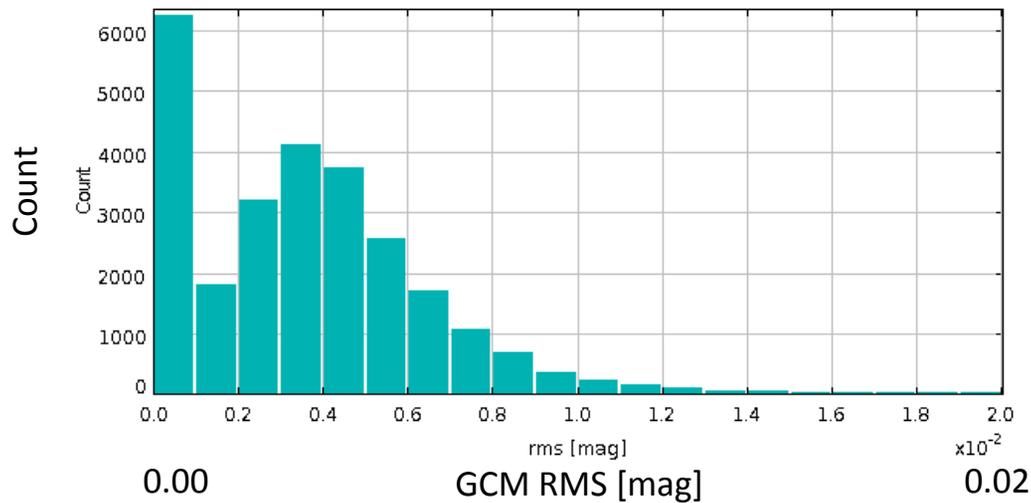
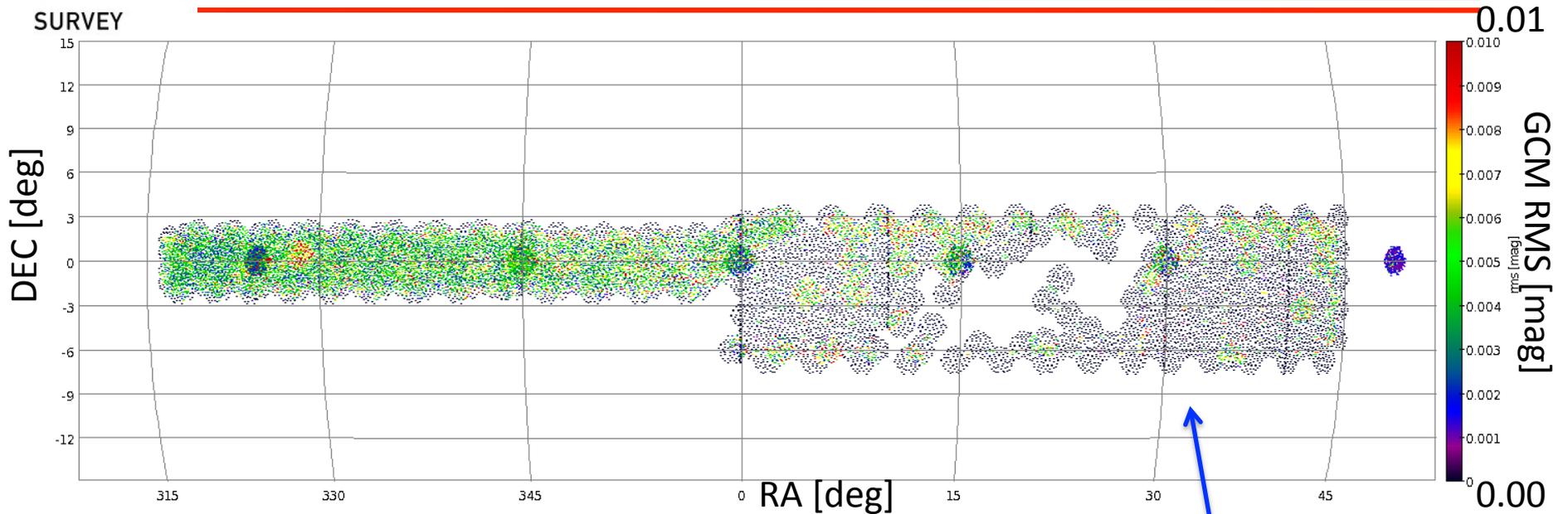


Each "point" is an
Individual CCD image



GCM RMS's (internal errors): z-band

DARK ENERGY
SURVEY



Each "point" is an
Individual CCD image

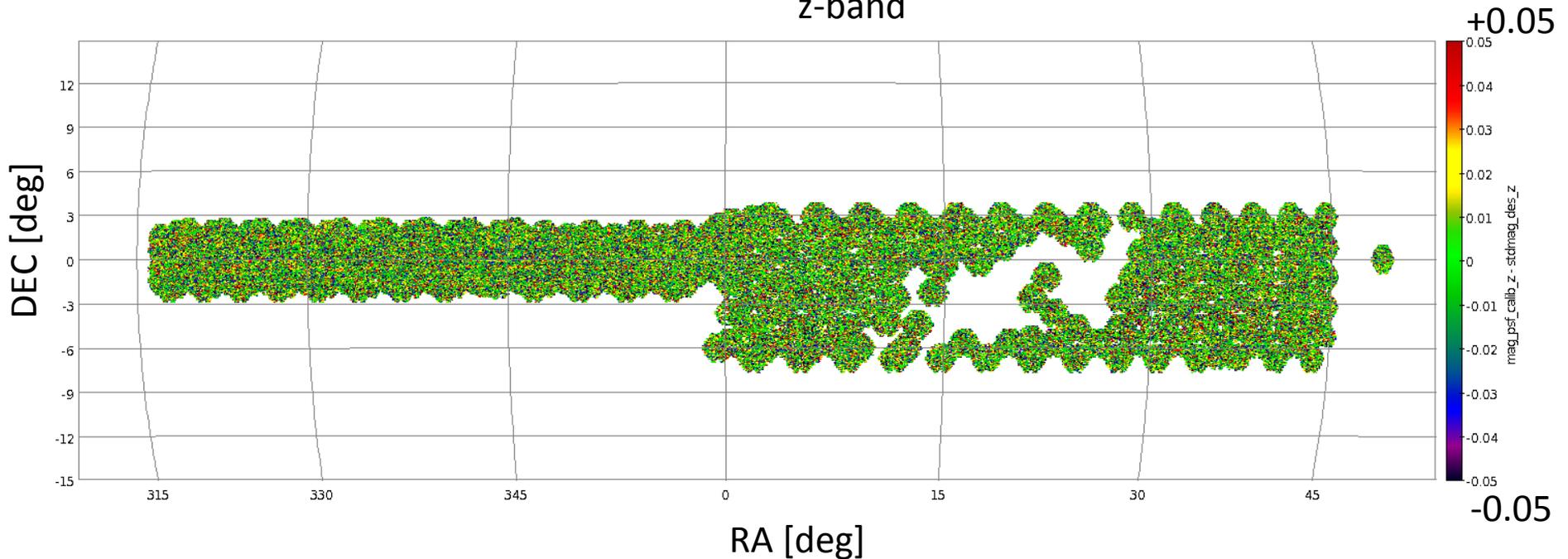
← (Note that the x-axis is in units of 0.01 mag)



DARK ENERGY
SURVEY

Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag*

GCM-calibrated mag_psf minus stdmag* vs. (RA,DEC):
z-band

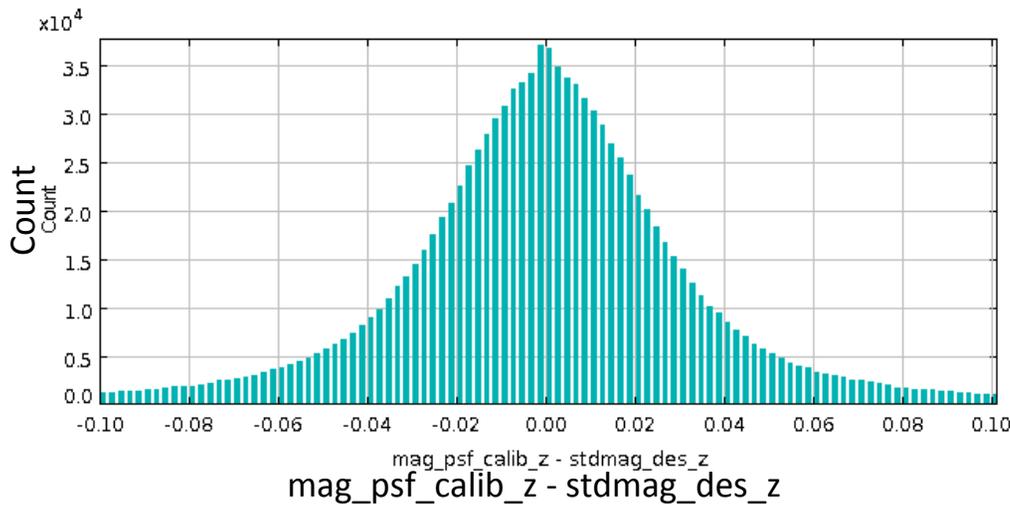
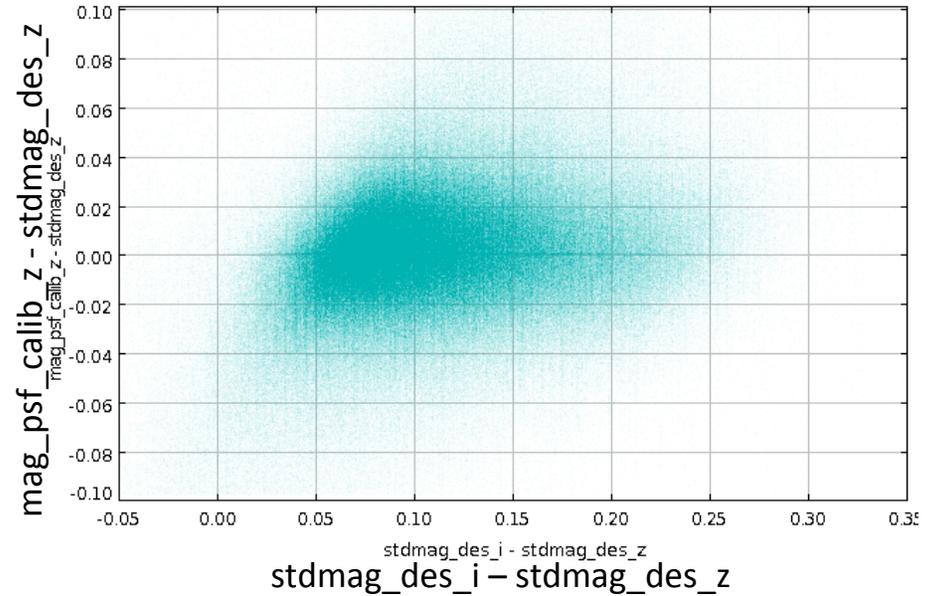
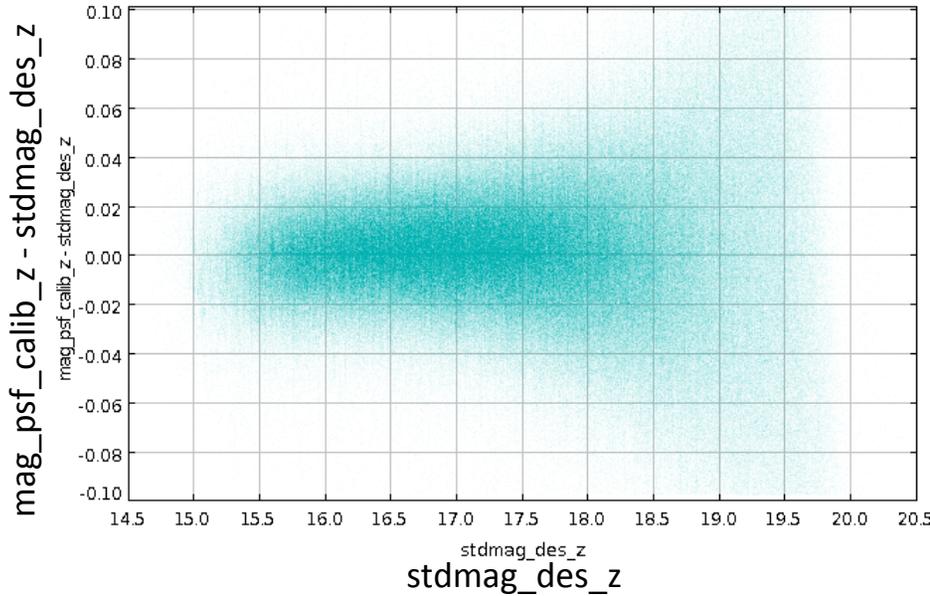


*stdmag = SDSS DR10 mag transformed to DES AB mag



Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag*

DARK ENERGY
SURVEY



↑
Residual color term?

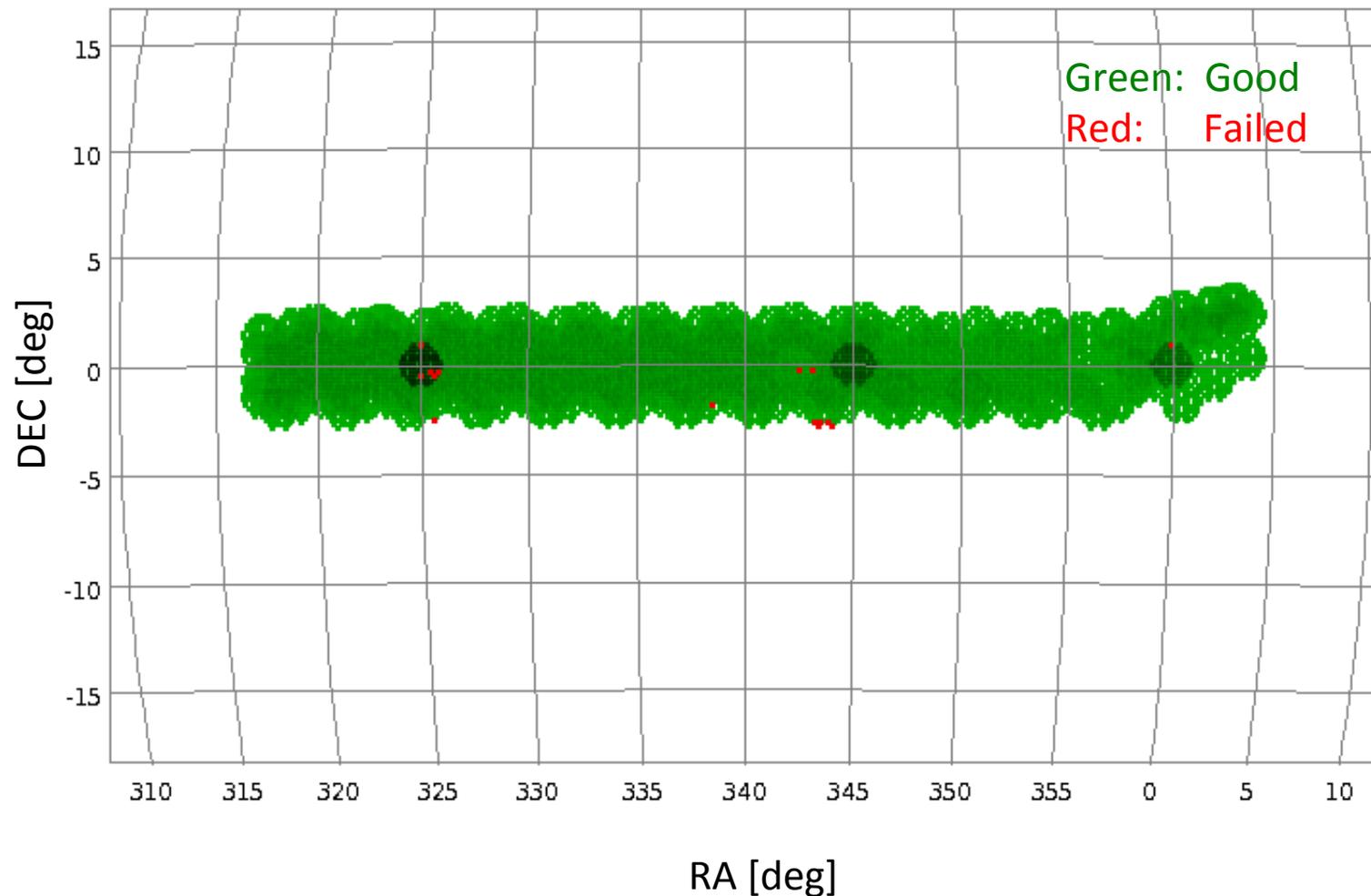
*stdmag = SDSS DR10 mag
transformed to DES AB mag



GCM Failed CCD Images in Strict Y1P1 Equatorial Area

DARK ENERGY
SURVEY

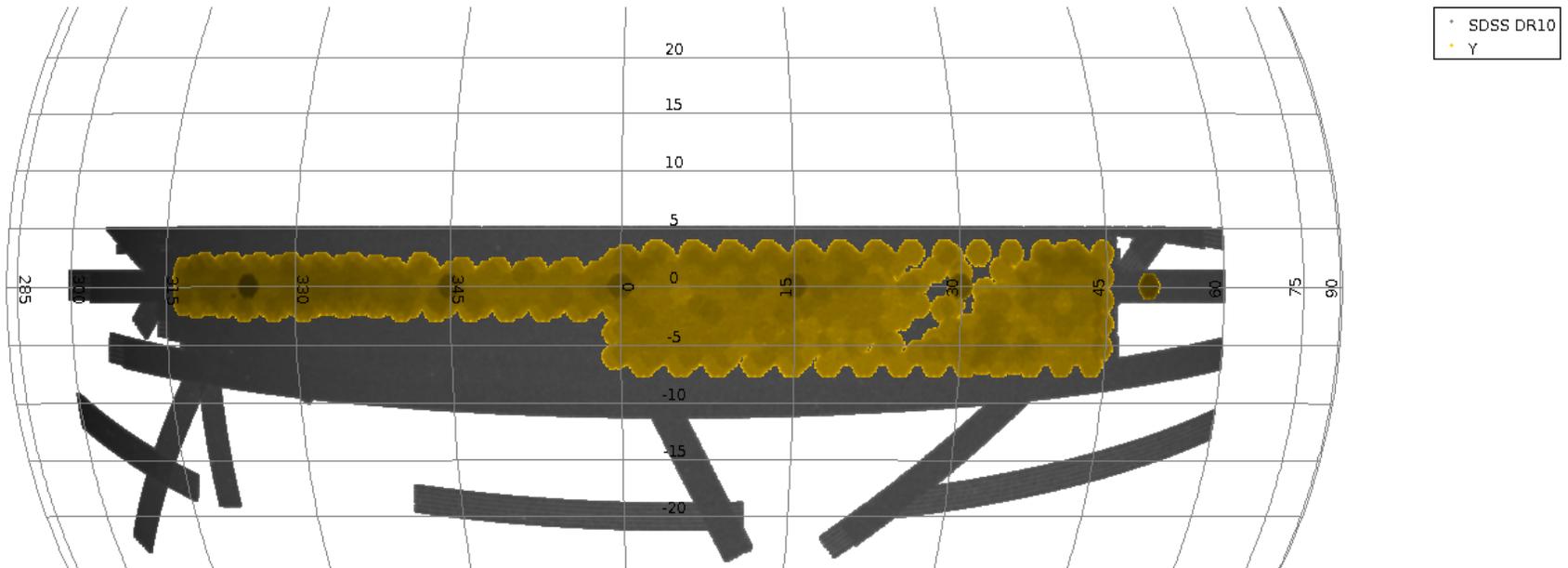
z-band: 15 failed out of total of 14,823 CCD images (0.10%)





Y1P1 Equatorial Area vs. SDSS DR10: Y-band

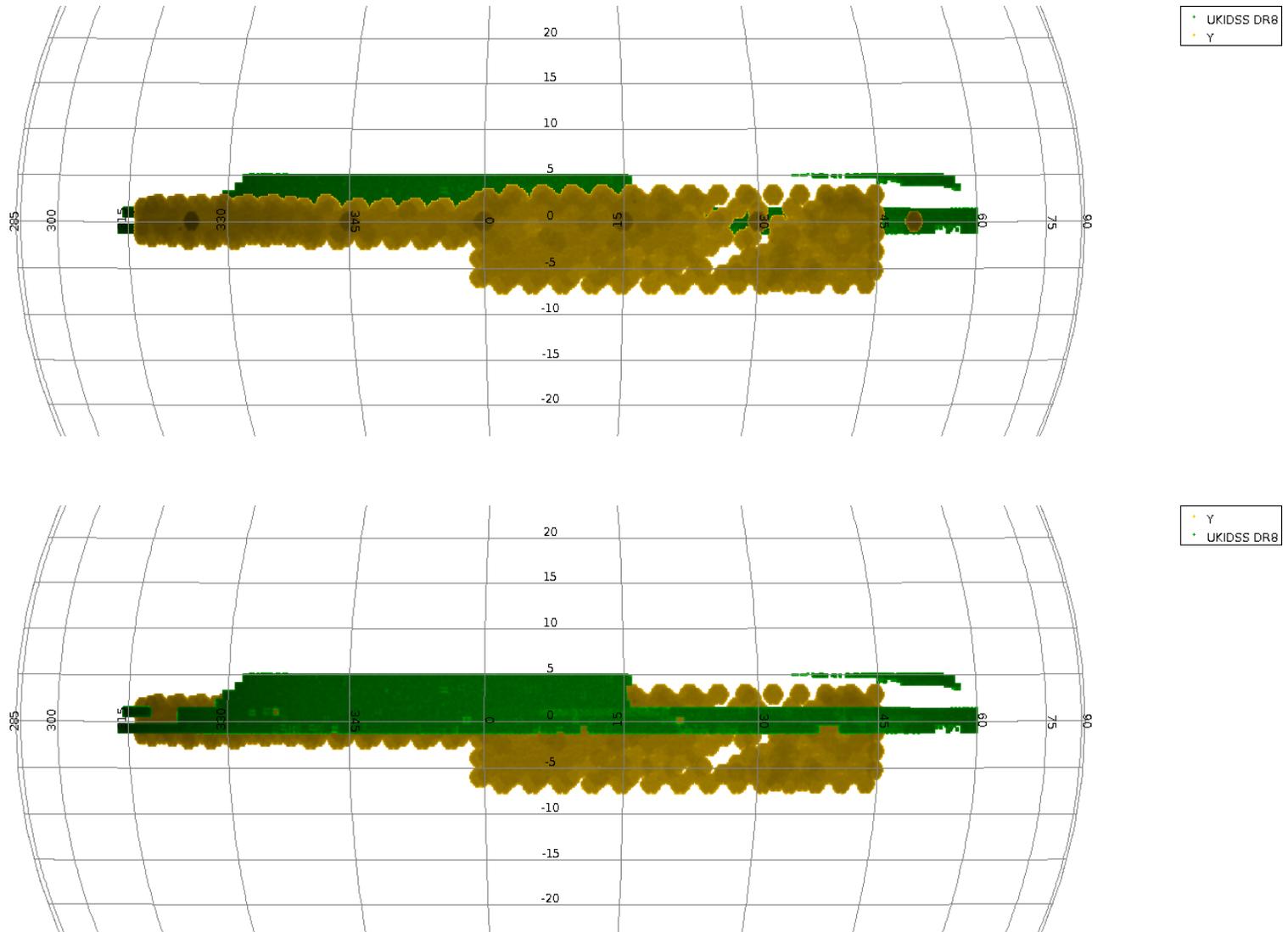
DARK ENERGY
SURVEY





Y1P1 Equatorial Area vs. UKIDSS DR8: Y-band

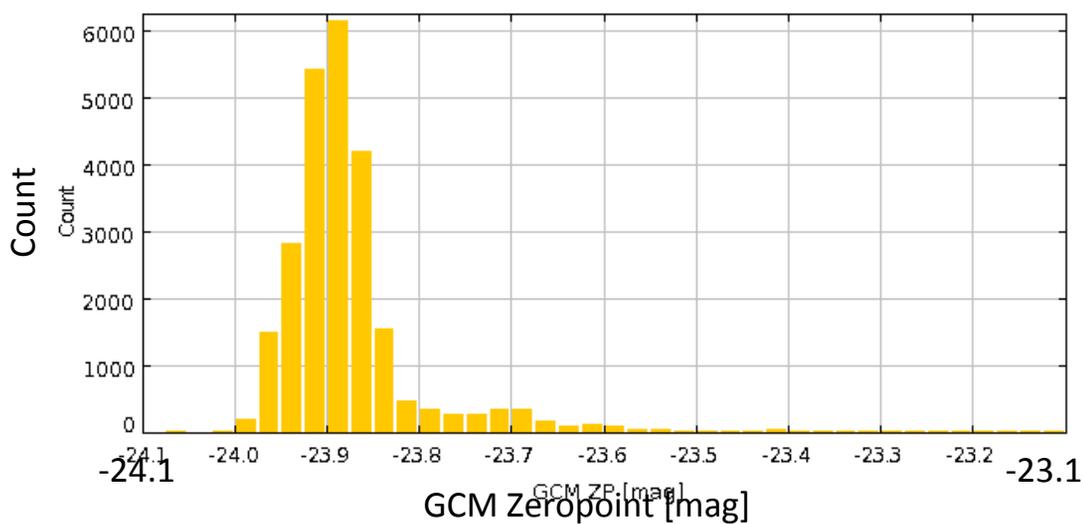
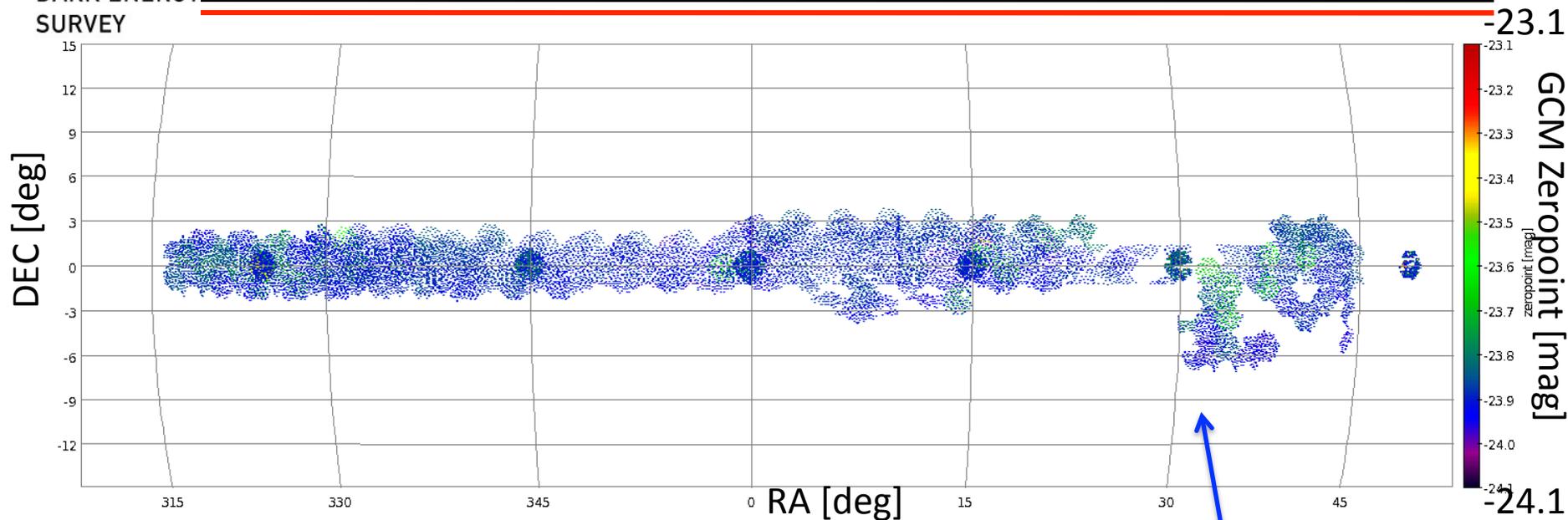
DARK ENERGY
SURVEY





GCM Zeropoints: Y-band

DARK ENERGY
SURVEY

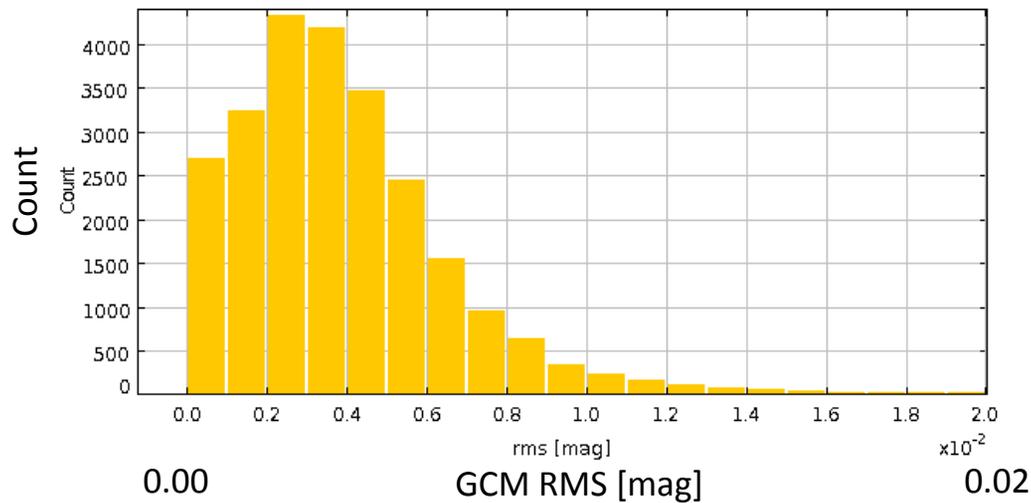
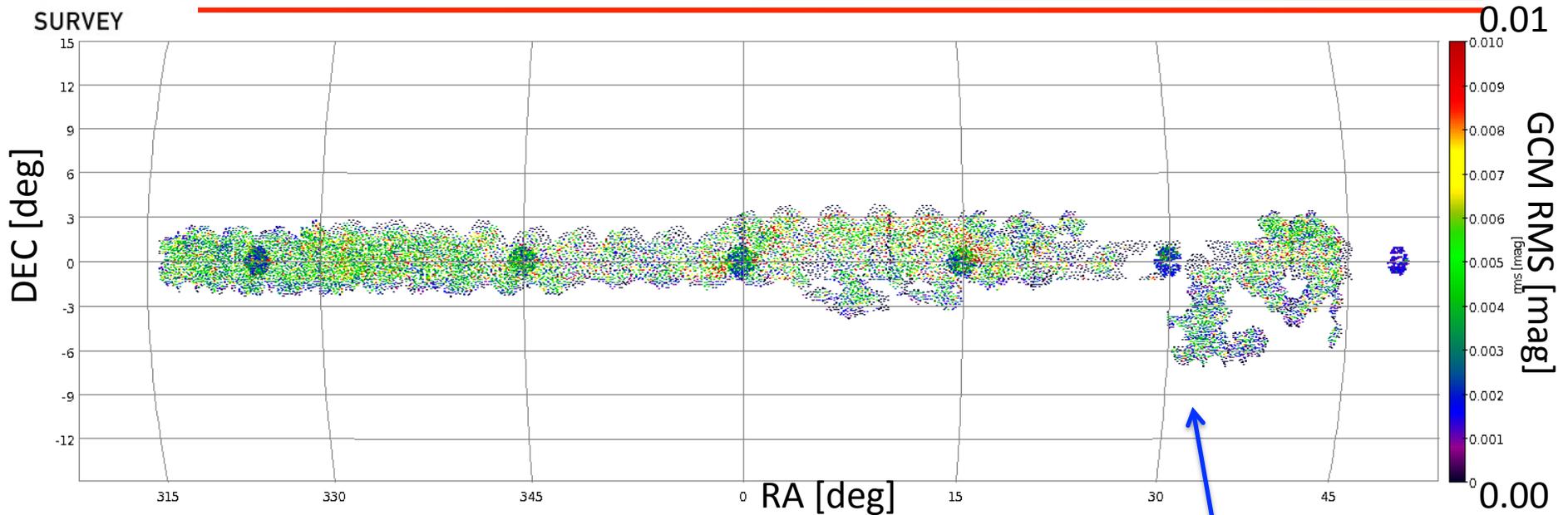


Each "point" is an
Individual CCD image



GCM RMS's (internal errors): Y-band

DARK ENERGY
SURVEY



Each "point" is an
Individual CCD image

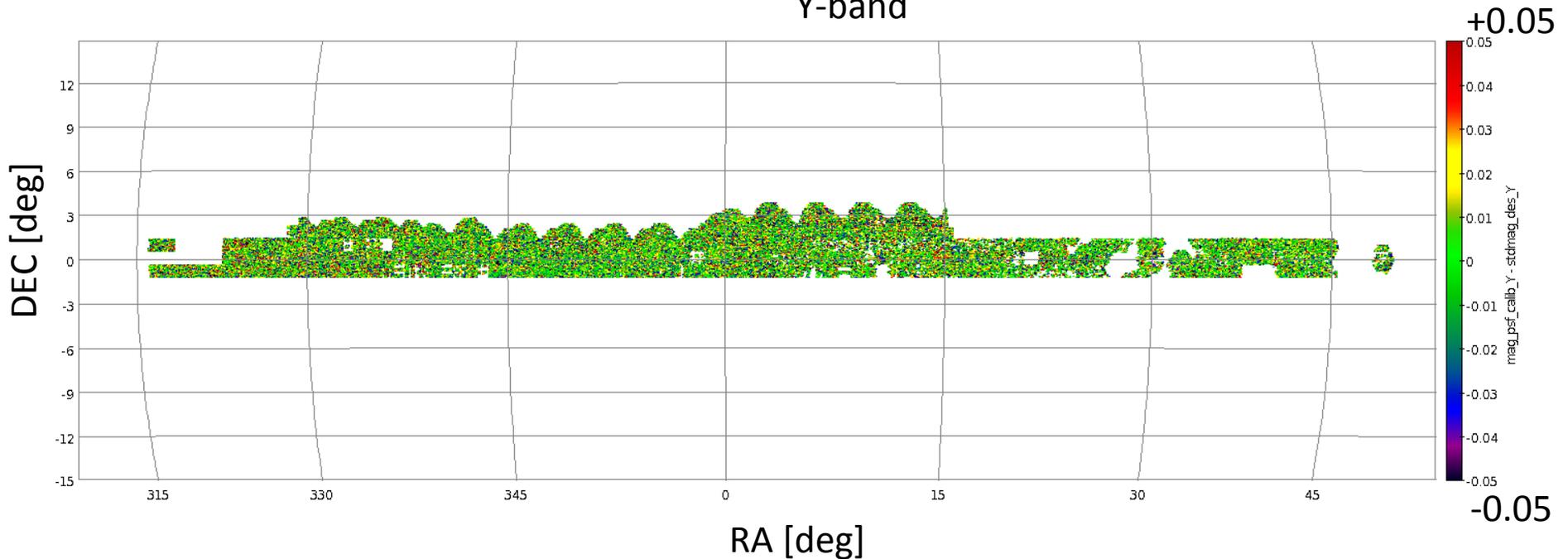
← (Note that the x-axis is in units of 0.01 mag)



DARK ENERGY
SURVEY

Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag*

GCM-calibrated mag_psf minus stdmag* vs. (RA,DEC):
Y-band

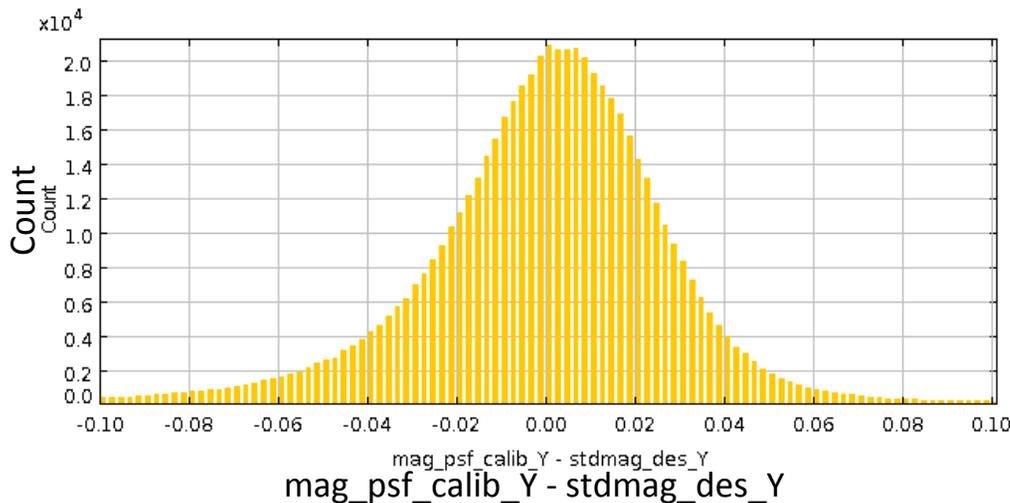
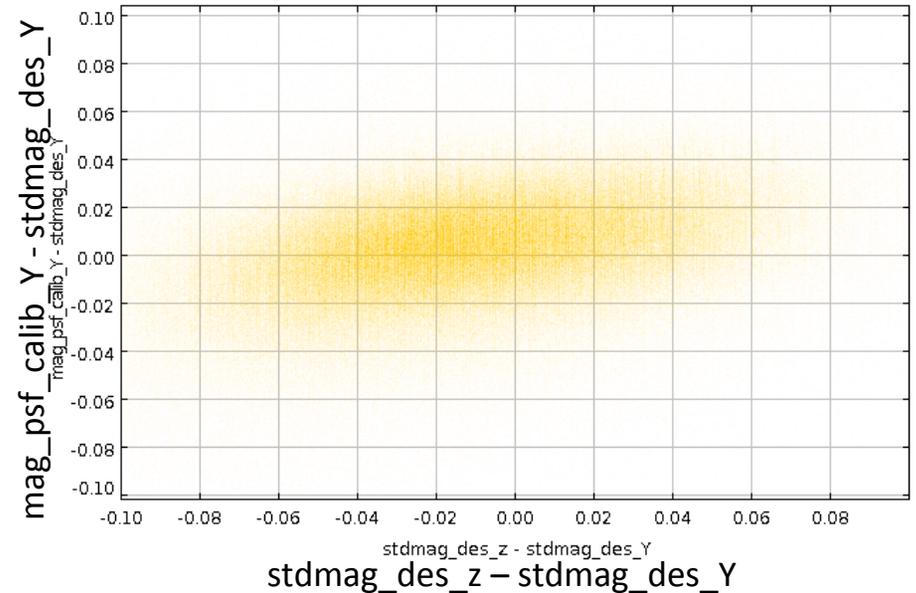
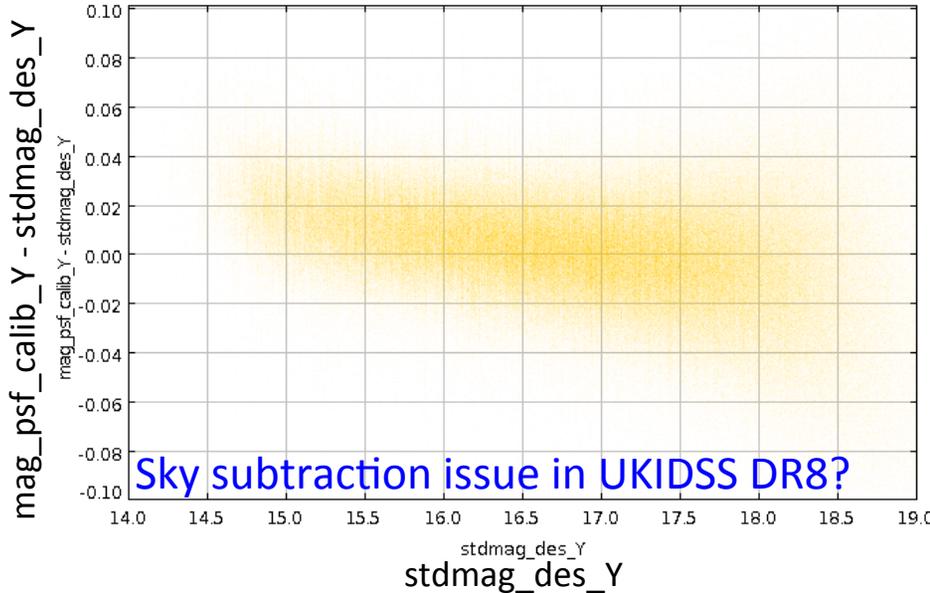


*stdmag = UKIDSS DR8 mag transformed to DES AB mag



Cross-Check for Systematic Errors: GCM-calibrated mag_psf vs. stdmag^*

DARK ENERGY
SURVEY



↑
Note residual color term

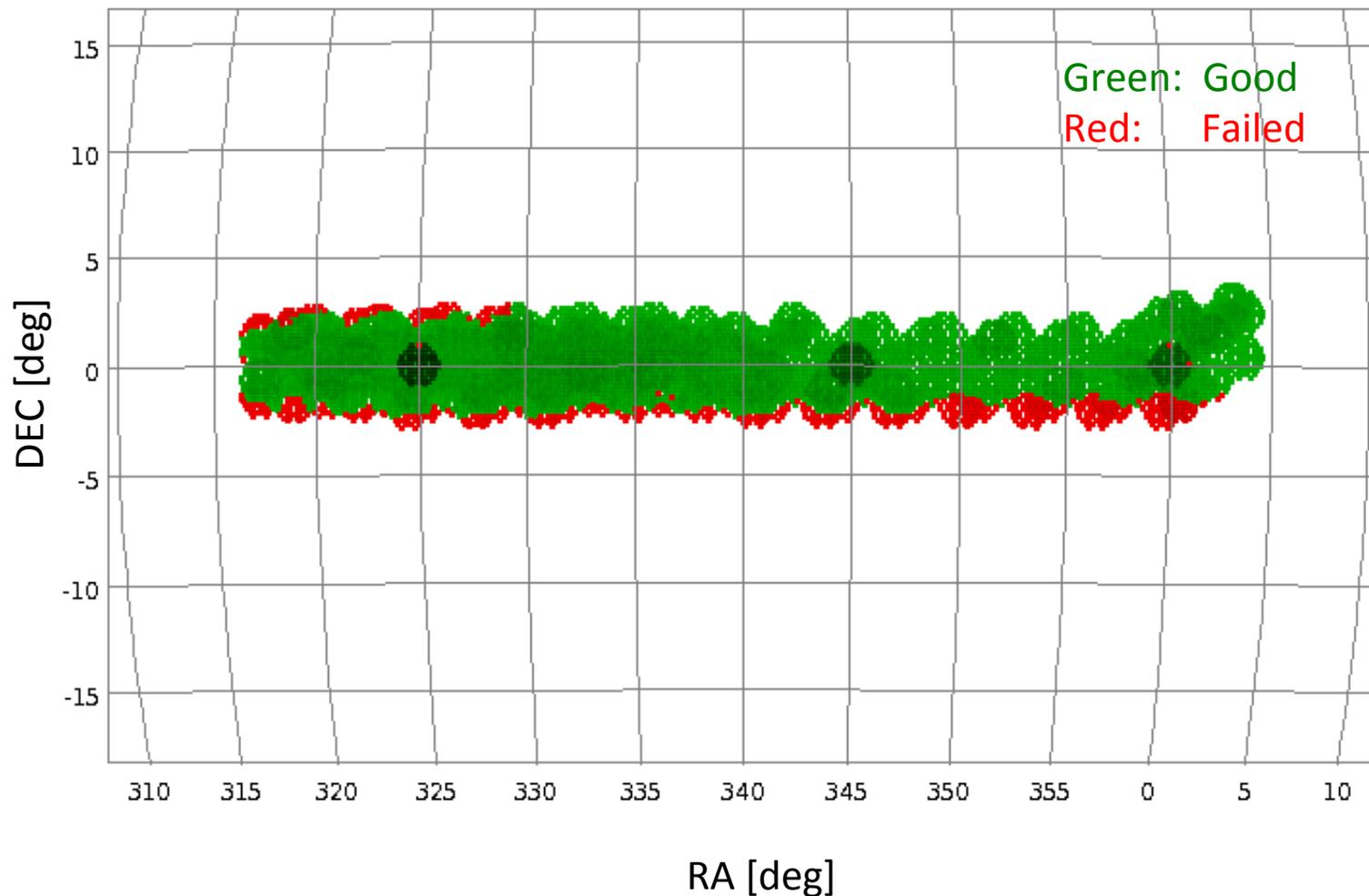
* stdmag = SDSS DR10 mag
transformed to DES AB mag



DARK ENERGY
SURVEY

GCM Failed CCD Images in Strict Y1P1 Equatorial Area

Y-band: 775 failed out of total of 13,786 CCD images (5.62%)

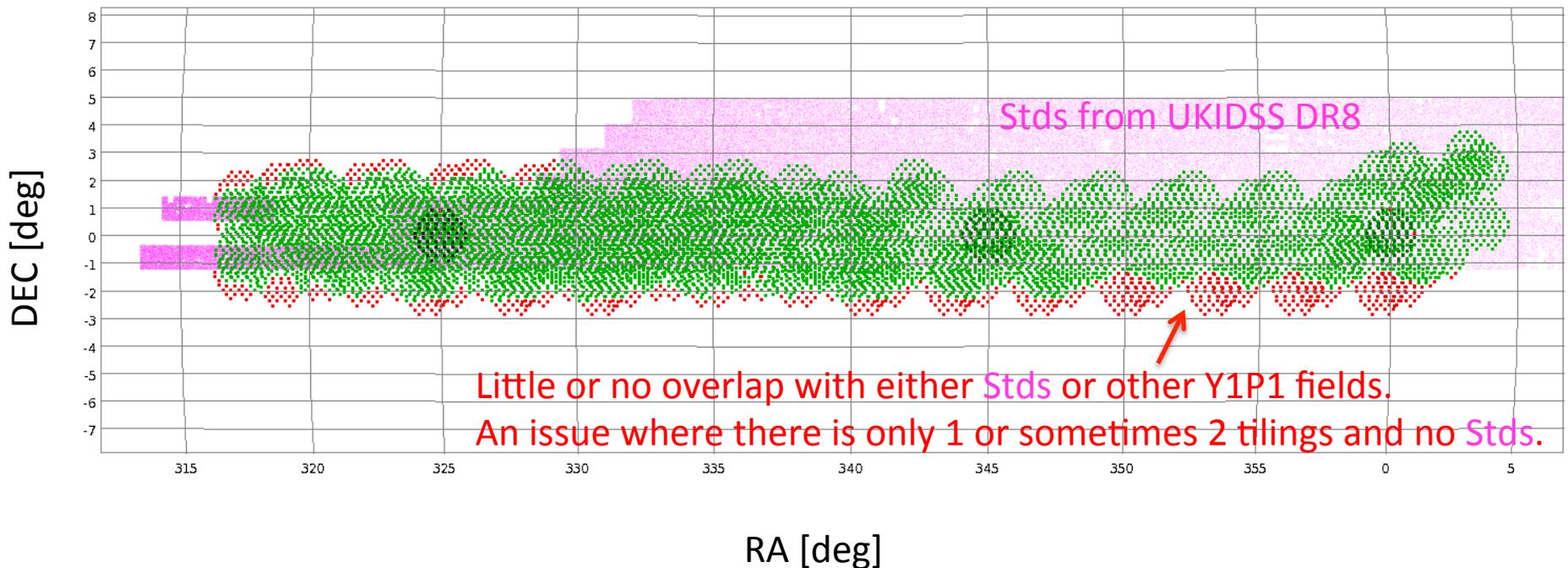




DARK ENERGY
SURVEY

GCM Failed CCD Images in Strict Y1P1 Equatorial Area

Y-band: 775 failed out of total of 13,786 CCD images (5.62%)



(GCM requires at least 5 stars in overlap between images.

This particular case could likely be improved by solving on an exposure by exposure basis
– as is planned for the Y1P1 SPT area – instead of a CCD image by CCD image basis.)



Stripe 82 Area Status and Summary

DARK ENERGY
SURVEY

1. Delivered grizY GCM zeropoints to NCSA on 21 Dec 2013 (plus additional QA on 27 Dec 2013).
2. Due to the substantial overlap with SDSS DR10, this region is very useful for testing. Although SDSS DR10 is not Truth, it does have “Truthiness”. In the future, we probably will want to test algorithms here rather than in the SVA1 SPT-East area.
3. Also practice with exposure-by-exposure calibrations in this area?



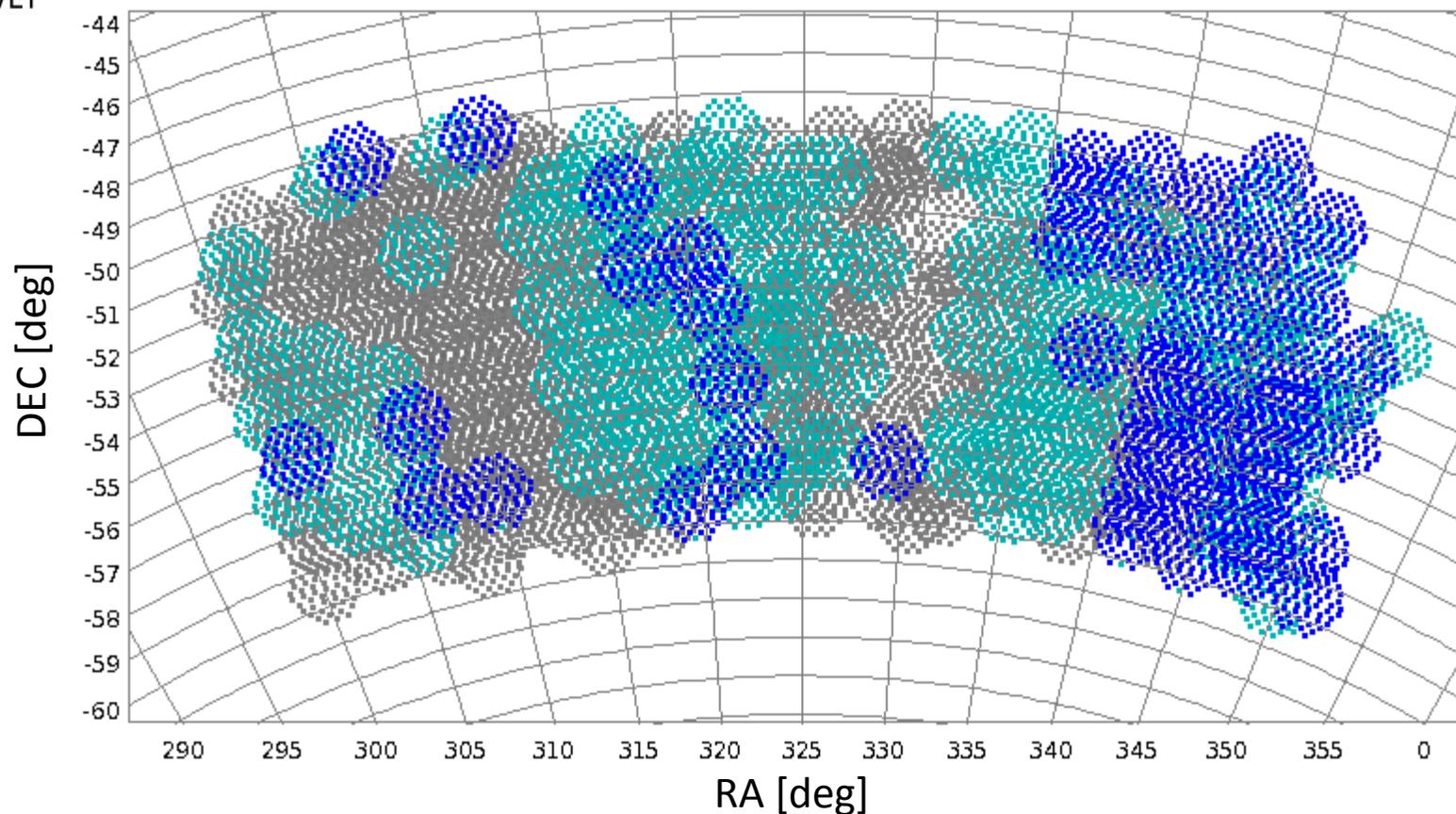
SPT Area

- Not much overlap with previously calibrated grizY standards stars
- Need to create local tertiary standards from PSM solutions.
- Calibrate SPTE in two steps:
 1. Calibrated photometric exposures on an exposure-by-exposure basis, tossing out dome occluded/non-photometric exposures iteratively, and tying to the local tertiary standards.
 2. Calibrate non-photometric/dome-occluded exposures on a CCD image by CCD image basis by tying to calibrated data from Step 1 (“quaternary standards”?).



Y1P1 SPT Area: g-band

DARK ENERGY
SURVEY



Gray: Non-photometric conditions*

Cyan: Photometric conditions*

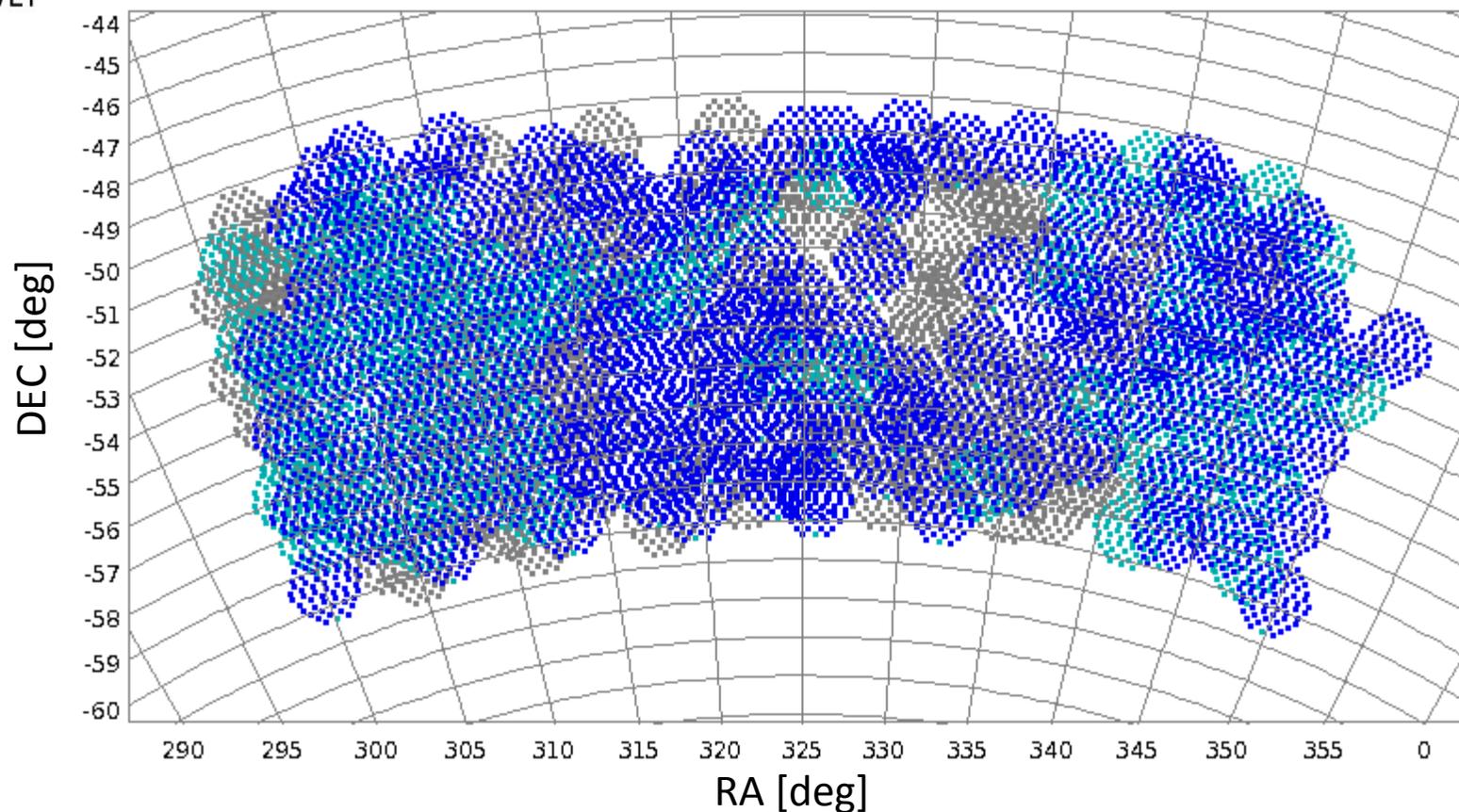
Blue: Photometric conditions* **AND** good std star ("PSM") solution for night

*According to RASICAM



Y1P1 SPT Area: r-band

DARK ENERGY
SURVEY



Gray: Non-photometric conditions*

Cyan: Photometric conditions*

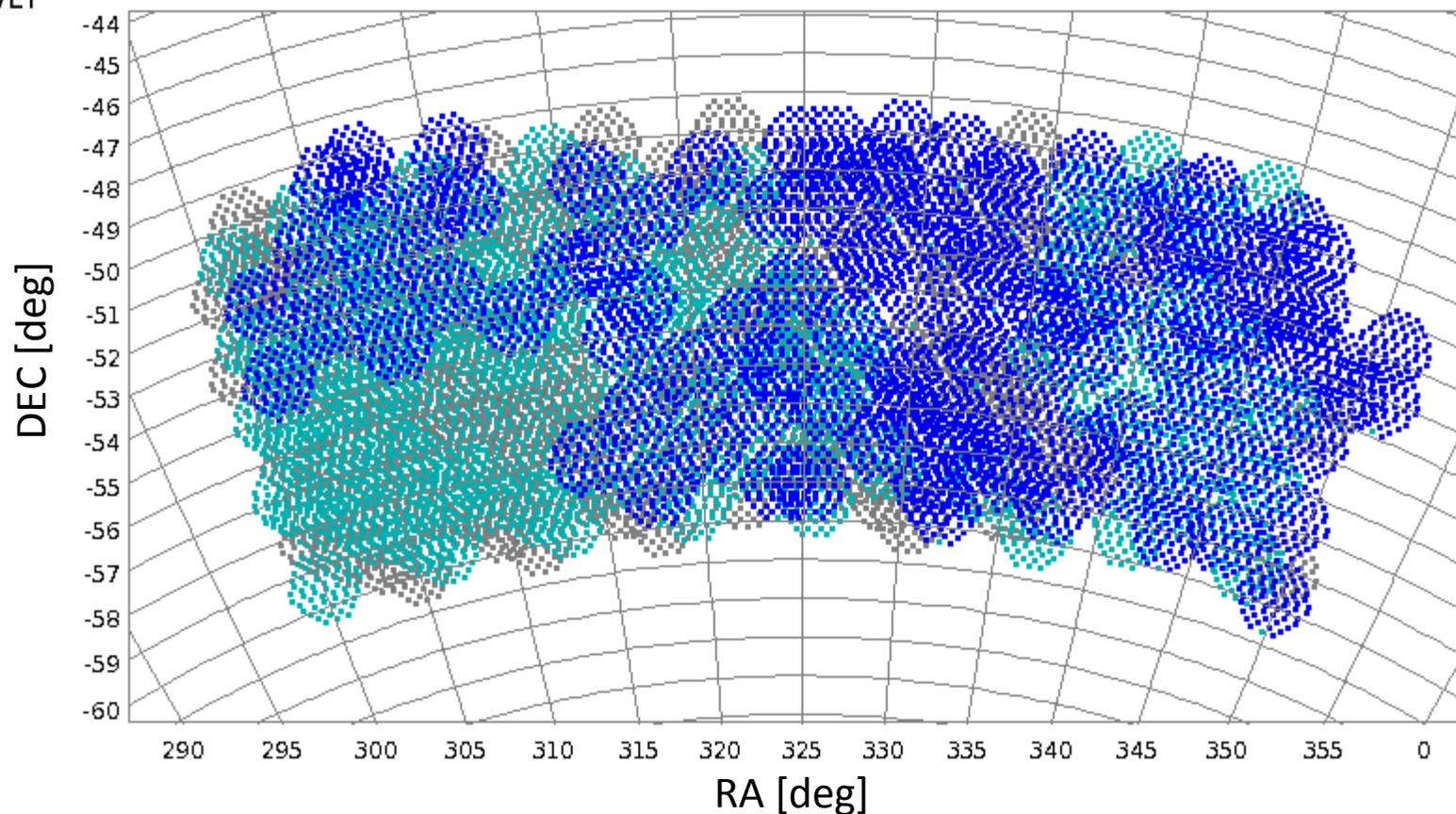
Blue: Photometric conditions* **AND** good std star ("PSM") solution for night

*According to RASICAM



Y1P1 SPT Area: i-band

DARK ENERGY
SURVEY



Gray: Non-photometric conditions*

Cyan: Photometric conditions*

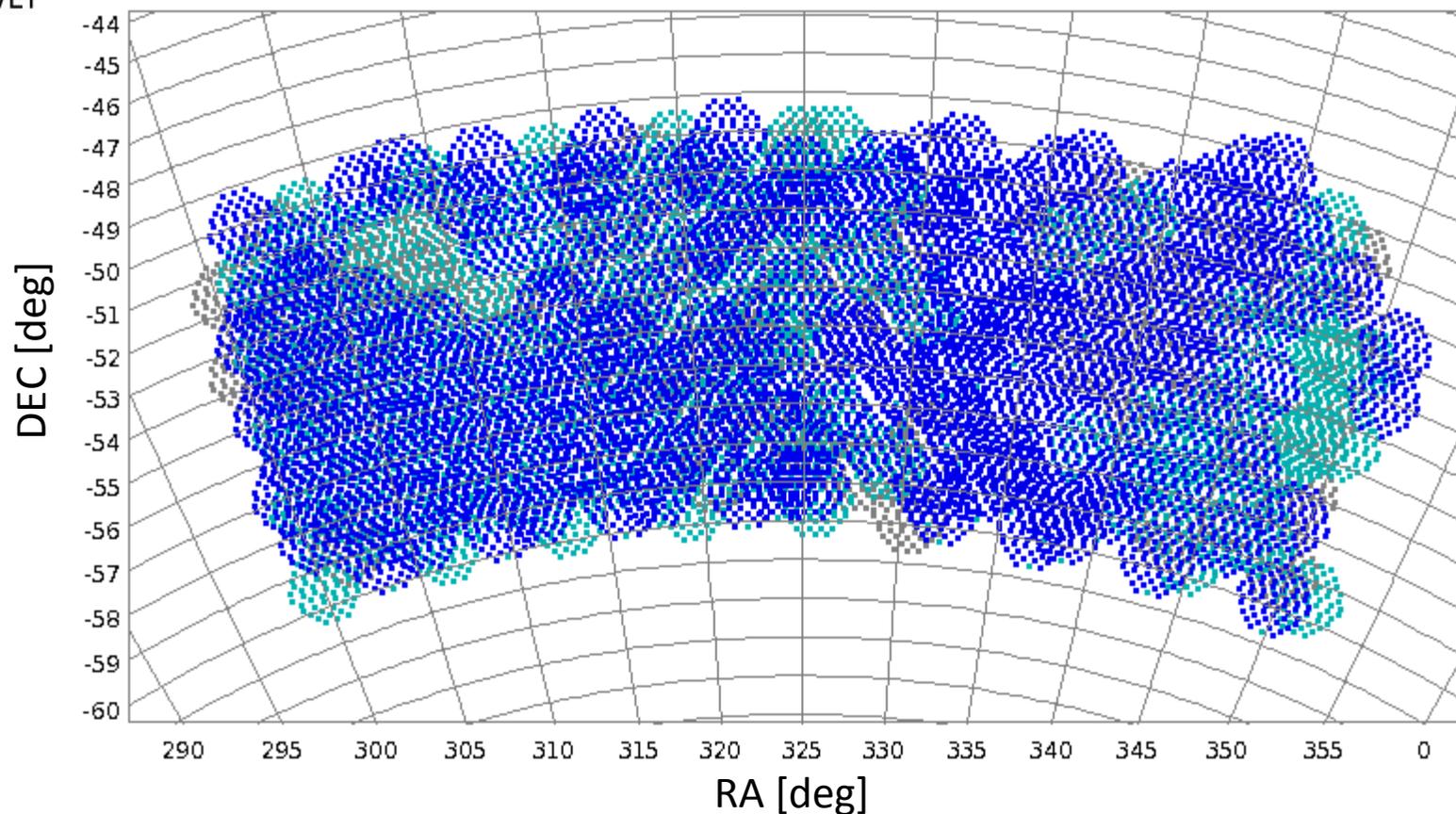
Blue: Photometric conditions* **AND** good std star ("PSM") solution for night

*According to RASICAM



Y1P1 SPT Area: z-band

DARK ENERGY
SURVEY



Gray: Non-photometric conditions*

Cyan: Photometric conditions*

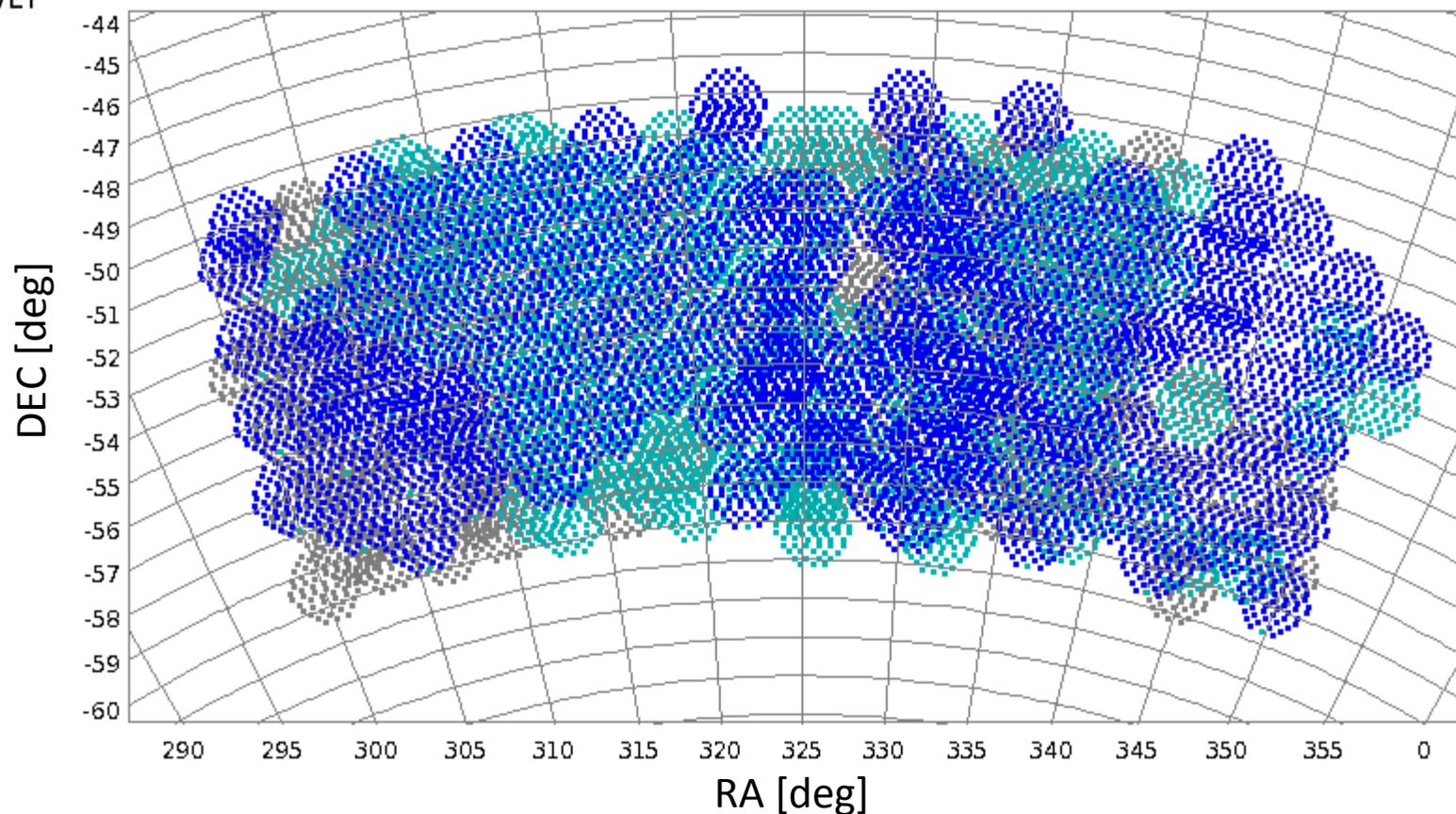
Blue: Photometric conditions* **AND** good std star ("PSM") solution for night

*According to RASICAM



Y1P1 SPT Area: Y-band

DARK ENERGY
SURVEY



Gray: Non-photometric conditions*

Cyan: Photometric conditions*

Blue: Photometric conditions* **AND** good std star ("PSM") solution for night

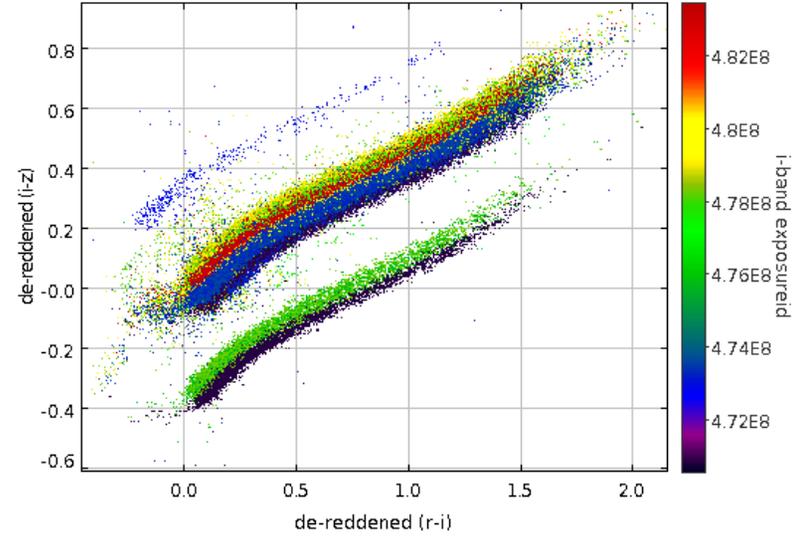
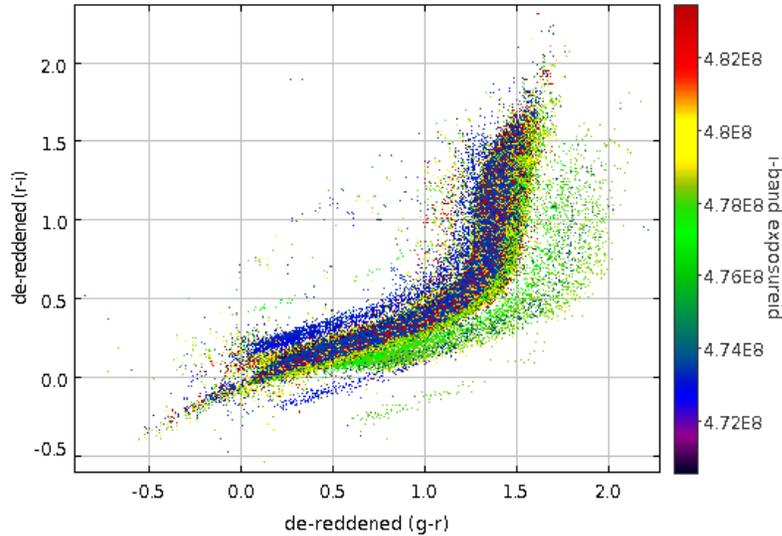
*According to RASICAM



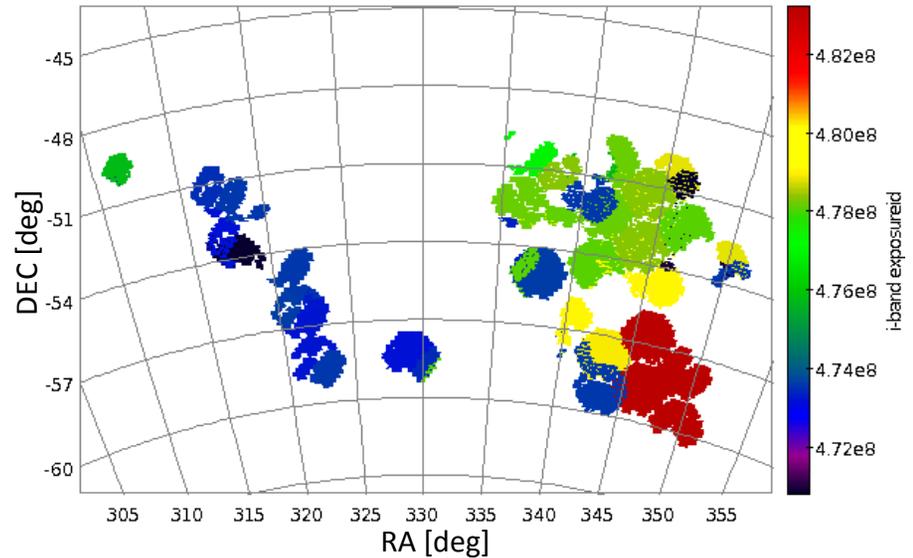
After Culling Non-Photometric* Exposures and Exposures w/o a Good PSM Solution

*As determined by RASICAM

DARK ENERGY SURVEY



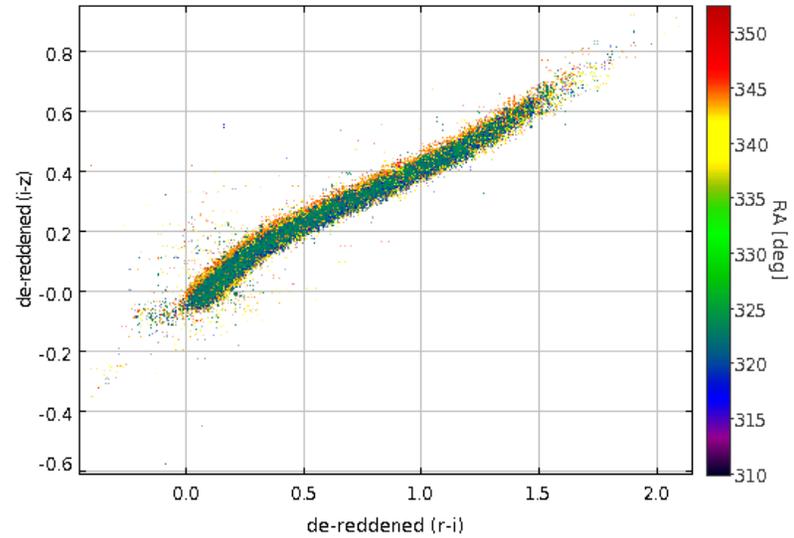
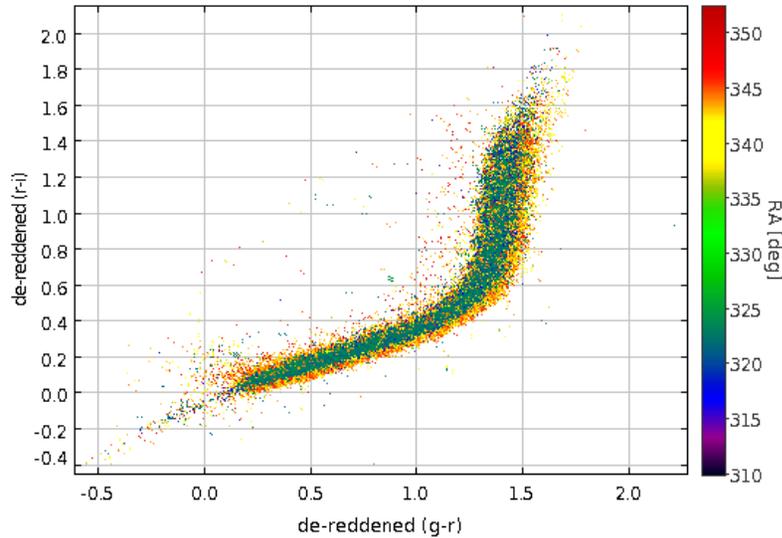
Symbols color-coded by i-band exposure id



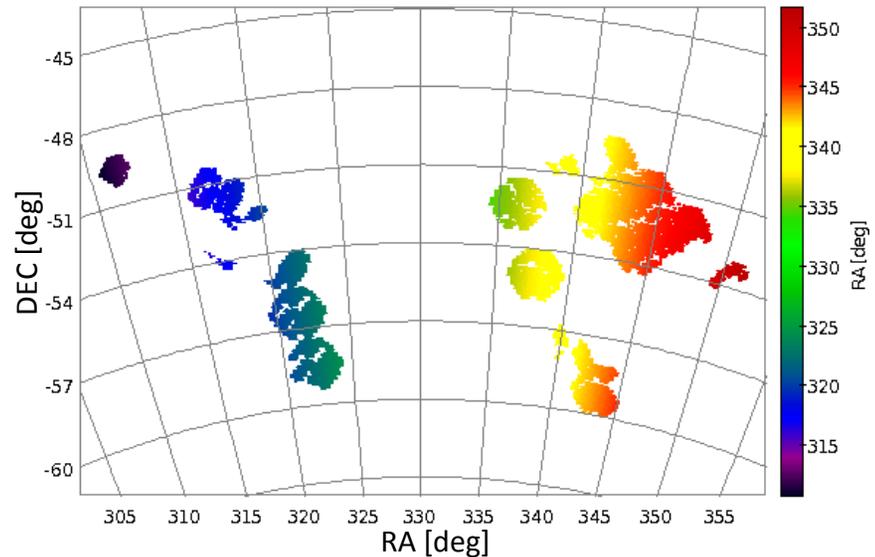


After Additional Culling... (Any remaining trends vs. RA?)

DARK ENERGY
SURVEY



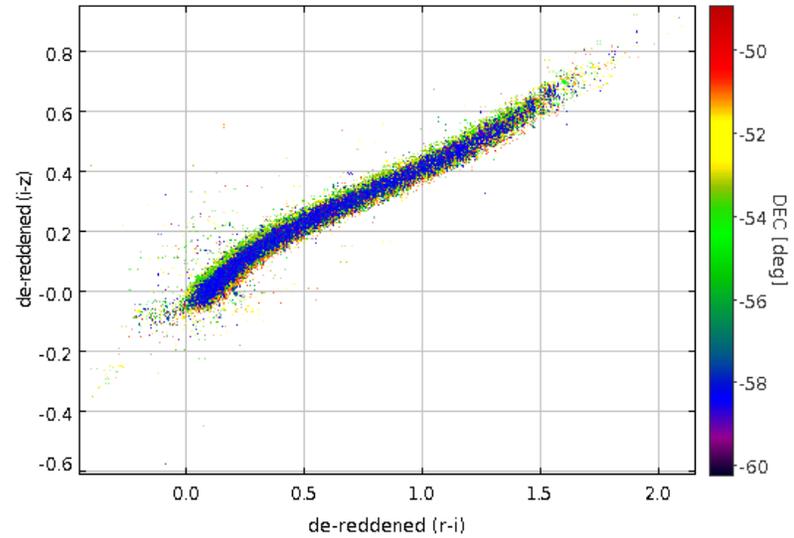
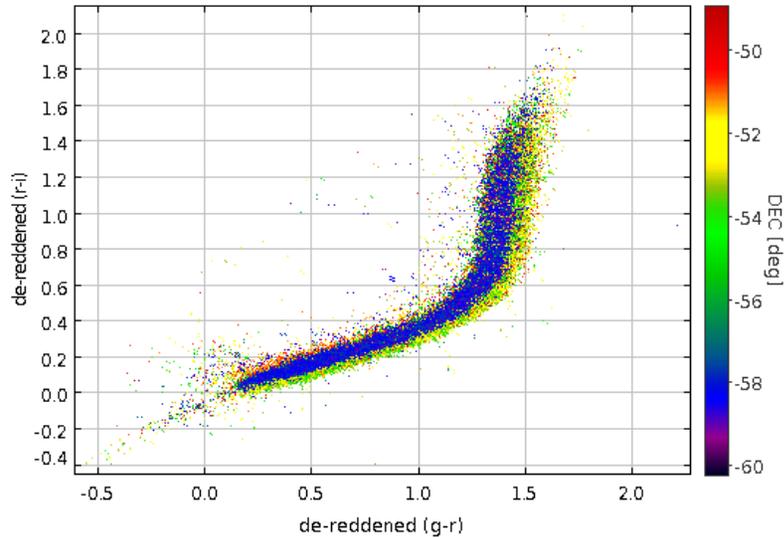
Symbols color-coded by RA



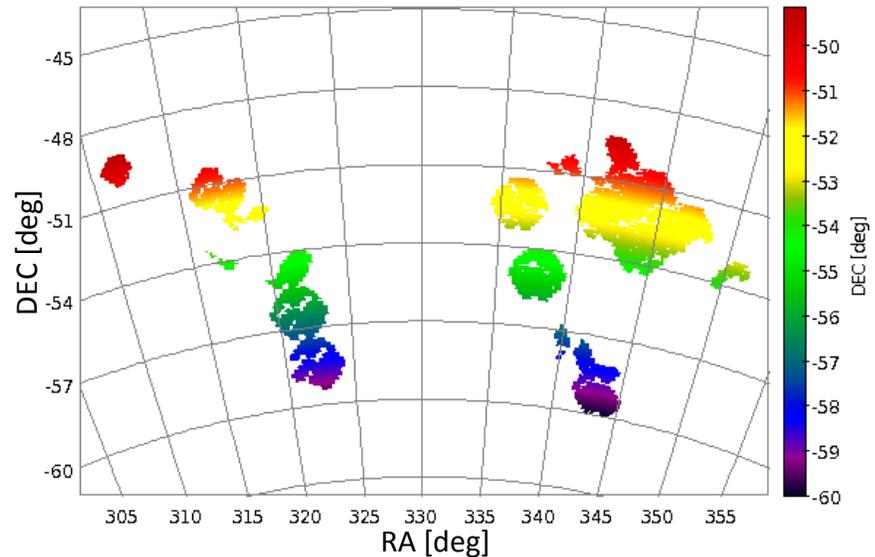


After Additional Culling... (Any remaining trends vs. DEC?)

DARK ENERGY
SURVEY



Symbols color-coded by DEC





SPT Area Status and Summary

DARK ENERGY
SURVEY

1. Working on generating local tertiary standards right now.
 - a. Ideally, a tertiary standard star has observations in all 5 DES bands (grizY) and at least 2 observations in each band.
 - b. Needed to relax the 2-obs.-in-each-band criterion for Y1P1 SPTW.
 - c. Useful check on tertiary standards: do their de-reddened stellar loci fall on top of each other?

2. Next: the exposure-by-exposure global calibrations of the exposures taken under photometric conditions
 1. Iterate to identify and cull dome-occluded exposures.
 2. Create a set of quaternary stds in these exposures based on zp's from this step.
 3. Some updates required in the scripts to accommodate exposure-by-exposure calibrations.

3. Then: ccd image-by-ccd image global calibrations of non-photometric exposures, tying to the quaternary stds from step 2.



DARK ENERGY
SURVEY

SN Areas

- Lots of overlap with previously calibrated DES grizY tertiary standards.
- Update previously calibrated DES grizY tertiary standards using new data from Year 1.
- Perform a single-pass GCM solution, solving for photometric zeropoints on a CCD image by CCD image basis.



SN Areas Status and Summary

DARK ENERGY
SURVEY

1. After SPTW.
2. Calibrate all SN exposures, or just those that make the DM cut? (DESDM wants just the smaller sample, for coadds; SNWG wants all, for single-epoch calibrations).
 - Also u-band and Y-band requested by SNWG – a request left over from SVA1.



DARK ENERGY
SURVEY

Extra Slides



Checking for Missing GCM-solved CCD Images in the Strict Y1P1 Equatorial Area (g-band)

DARK ENERGY
SURVEY

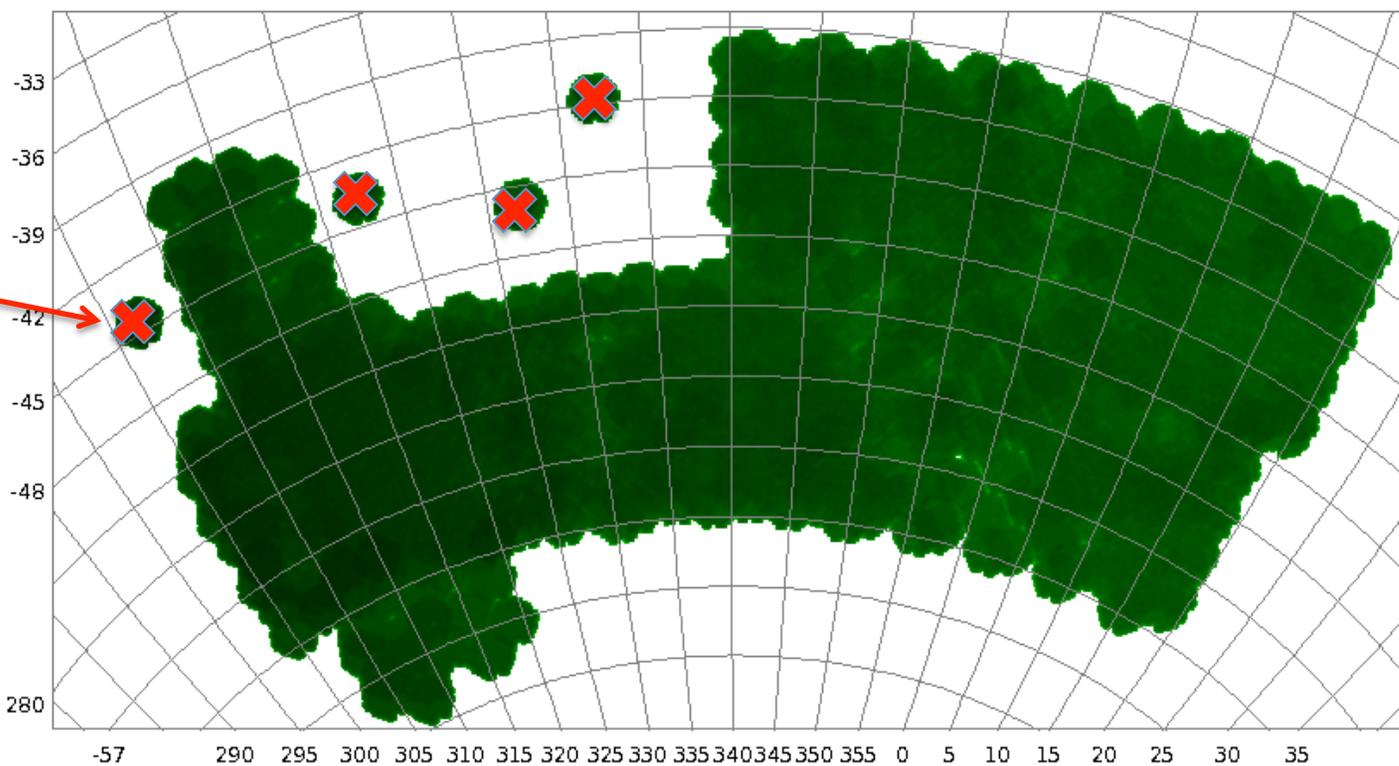
```
SELECT e.expnum, i.exposureid, i.id, i.ccd, i.ra, i.dec
FROM exposure e
  JOIN image I ON i.exposureid=e.id
  JOIN runtag r ON r.run=i.run
  JOIN exposuretag exptag ON e.id=exptag.exposureid
WHERE (exptag.tag='Y1P1_STRIPE82') AND
      (r.tag='Y1N_FIRSTCUT') AND
      i.imagetype='red' AND
      i.ccd!=61 AND
      e.band='g'
ORDER BY e.expnum, i.ccd
```



DARK ENERGY
SURVEY

Y1P1 SPT Area: g-band

Ignore these
isolated
exposures





DARK ENERGY
SURVEY

Lessons Learned/Action Items: Overall

(September 2013)

1. Convert from prototype “bash” scripts to Python.
2. Lots of SN field exposures have poor image quality – include them in the GCM solution?
3. Be aware of inconsistent naming conventions for some fields (should not be a problem for DES Operations, now that all science fields are run through ObsTac).
4. Need to farm out more of the work to other GCM experts once the process is more settled.



Lessons Learned/Action Items: Pre-Calibrate Step (Tertiary Standards)

(September 2013)

DARK ENERGY
SURVEY

1. Need RASICAM quantitative measures to identify and exclude exposures taken under non-photometric conditions (**big time sink to do by hand!**). **[Also: Dome Occlusions!!!]**
2. Occasionally, the local tertiary standards for an SV area (particularly for the SN fields) have a gap in coverage for one or more CCDs. This needs to be tracked down.
3. A lot more nights are failing to achieve a good PSM solution than should be the case (> half?). Could the nightly standard star high-airmass fields be suffering more than usual from the “dome occlusion” problem? **[YES!]**
4. Although it could not be done for SV-A1 – due to big changes in the calibration after Y1C2 – for next year, it would make sense to create tertiary standards as soon as FirstCut is done.



DARK ENERGY
SURVEY

Lessons Learned/Action Items: StarMatch Step

(September 2013)

1. Use faster matching algorithms (relatively minor point).



DARK ENERGY
SURVEY

Lessons Learned/Action Items: GCM-Zeropoint Step

(September 2013)

1. Quality of local tertiary standards important, especially for large areas like SPT-E where tertiary standard coverage will be spotty. Iterating the loop PreCalibrate-StarMatch-GCMzp-PreCalibrate-... when things go wrong is time-consuming.
2. For DES Operations Year 1, probably need a hex-worth of tertiary standards for about every 100-225 sq deg (about every $10^\circ \times 10^\circ$ to $15^\circ \times 15^\circ$) – or about 10-25 calibrated hexes over the DES Operations Year 1 Footprint.
3. For the current GCM algorithm, which appears to be an N^3 process (where $N = \#$ of unique and independent ccd images), solutions for $N > 15,000$ per filter band become prohibitively long to complete (>1 day). Need to break up DES area into manageable “chunks.”



DARK ENERGY
SURVEY

Lessons Learned/Action Items: Handoff to NCSA Step

(September 2013)

1. Current process seems to work OK as a temporary solution.
2. Need to plan what to do for next year.
 - a. Plan should be general enough to handle future incarnations of Uebecal-like calibrations (YaCal, PennCal, ...)